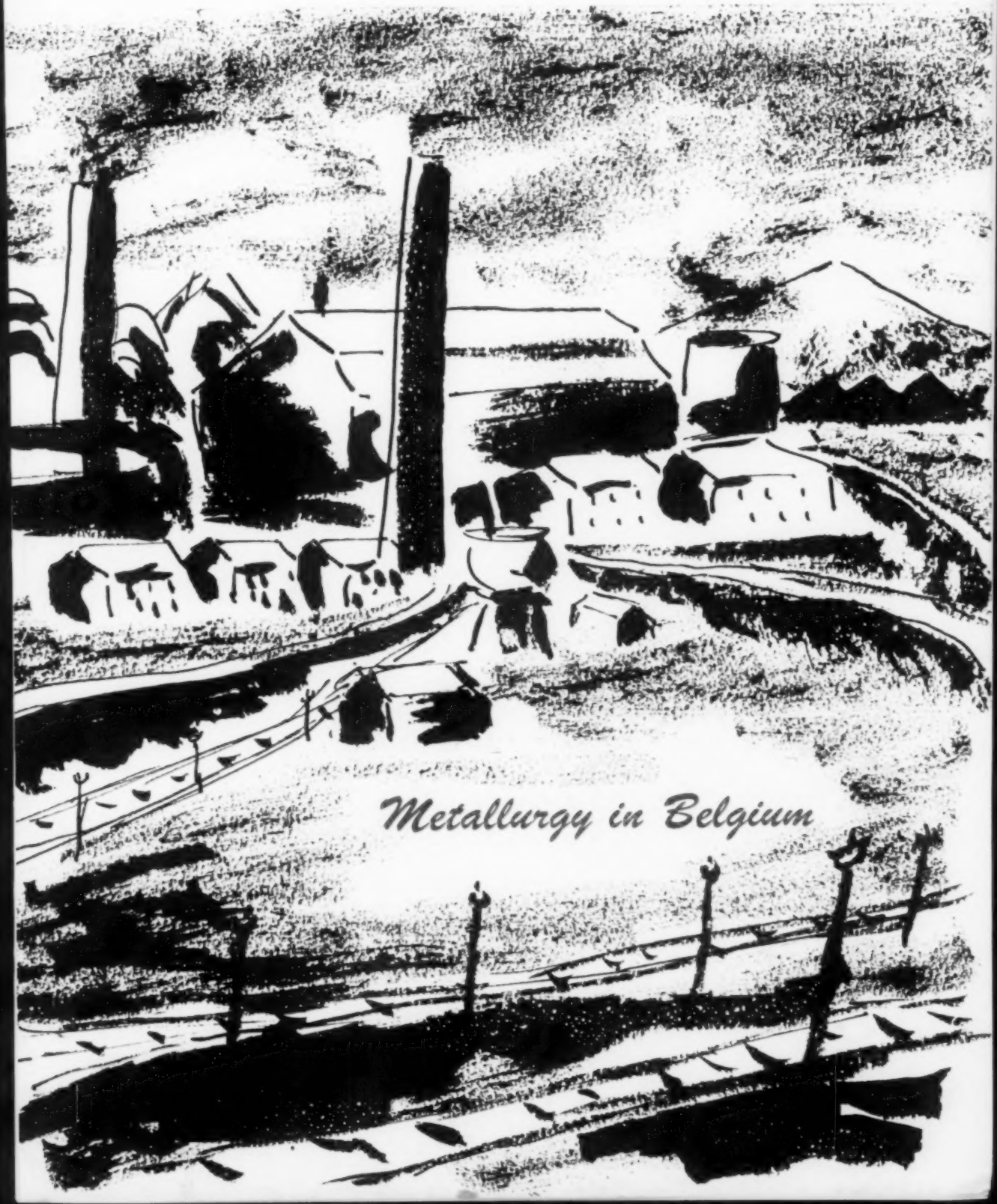
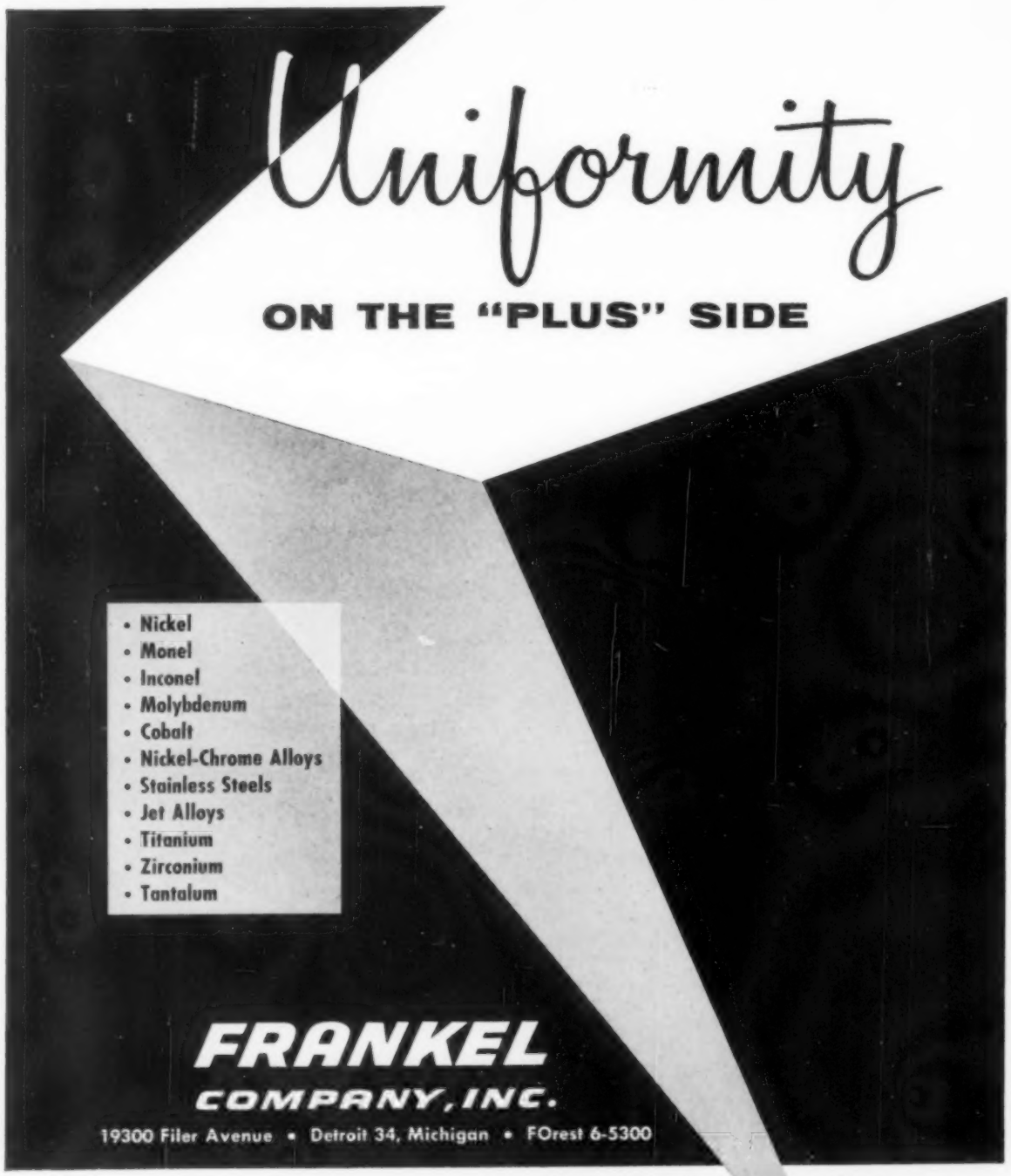
JOURNAL OF

METALS

OCTOBER 1958



Metallurgy in Belgium



Not a single piece of scrap making up your shipment of secondary alloys from Frankel contains less than the amount of alloying agents you specify. This means that the average content of the alloying agents is to the maximum side of your specification.

That's your standard Frankel bonus. You pay nothing for it.

No wonder more and more buyers of secondary special alloys are turning to Frankel.

JOURNAL OF

METALS

Vol. 10, No. 10
October, 1958

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COVER: This month the "New Look" has finally reached the cover of Journal of Metals as we begin to explore a new style with our new artist, David Cain. The scene . . . metallurgical plants and coal mines of Belgium . . . introduces this issue, which is dedicated to the metallurgists of Belgium.

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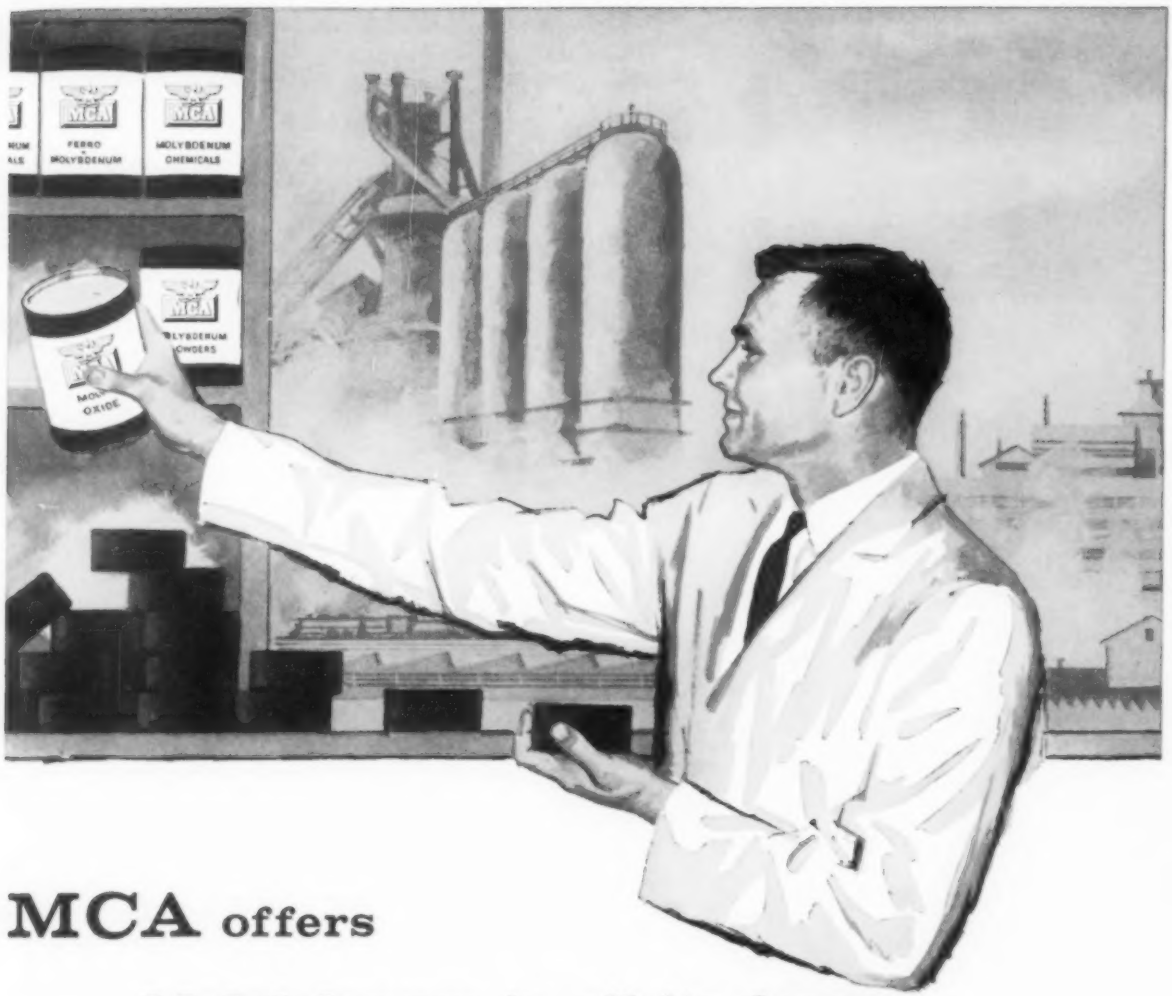

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PERSONNEL

THE following employment items are made available to AIME members on a nonprofit basis by the Engineering Societies Personnel Service, Inc. (Agency) operating in cooperation with the Four Founder Societies Local offices of the Personnel Service are at 8 W. 40th St., *New York 18;* 100 Farnsworth Ave., *Detroit;* 57 Post St., *San Francisco;* 84 E. Randolph St., *Chicago 1.* Applicants should address all mail to the proper key numbers in care of the New York office and include 8c in stamps (no stamped envelopes) for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

—MEN AVAILABLE—

Consulting Firm Staff or Plant Supervisory Position desired, B.S. Met. E., age 55. Twenty-eight years broad experience in extractive metallurgy of lead, copper and zinc. Thirteen years superintendent and seven years department metallurgist lead smelting; eight years research laboratory and milling, nonferrous. Location, immaterial. #687 San Francisco.

—POSITIONS OPEN—

Metallurgist, for precision casting duties in nonferrous foundry. Salary $6000 year. Location, New Hampshire. W6477.

Metallurgist, preferably with precision casting and steel foundry experience. Salary, $7500 year. Location, Long Island, New York W6198.

Metallurgical Engineer or **Metallurgist,** graduate with production process. Salary, $6000-$8000 year. Location, vicinity Newark, New Jersey. W6041.

Metallurgist, engineering degree, plus experience in practical metallurgy and fabrication of carbon and stainless steels. Knowledge of fuel element fabrication and/or other metallurgical and fabrication applications peculiar to atomic power generation desirable. Location, Canada. W6410

Metallurgist in ferrous wire processing, graduate Met. E. Must have at least five years experience in wire mill, drawing and finishing low carbon wire and be able to set up quality controls, standards and production controls. Broad opportunity for advancement. Salary open. Location, southern Illinois. C6943.

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Outstanding young chemical, metallurgical, mechanical, industrial engineers and chemists, with 0-6 years experience, are invited to apply for production, development and engineering positions in Colorado.

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Union Carbide Nuclear Company
Division of Union Carbide Corporation
P. O. Box 1049
Grand Junction, Colorado

Patent Liaison Engineer, with degree in chemistry, metallurgy or physics, with some experience in invention reporting, disclosure preparation and general patent liaison work. Must be capable of operating without supervision and be able to deal tactfully with all levels of scientific, engineering, and administrative personnel. Will be in charge of small patent liaison casting, rolling and fabrication of nonferrous metals. Salary, $10,000-$14,000 year. Location, New York Metropolitan area. W6463.

Department Head for school of engineering; Ph.D. required, to head up metallurgical work. Must be promising young man who recently obtained Doctor's degree in metallurgical engineering. Salary open. Location South. W6455

Sales Engineer, engineering background, to contact metal fabricators in order to obtain business for company. Must have good contacts in industry. Salary open. Headquarters Pennsylvania. W6425

Powder Metallurgist, graduate, experienced in making nonferrous parts, i.e., processing and production. Salary, $7500-$10,000 Salary, $6300-$8520 year. Location upstate New York, W5534.

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PHYSICAL—B.S. in metallurgy or BMetE minimum requirement, M.S. in metallurgy preferred. A challenging, responsible position in applied research on melting, casting, alloying, and purification of beryllium. Research experience is necessary and preference will be given to backgrounds involving light or reactive metals.

RESEARCH—B.S. in metallurgy or BMetE minimum requirement, M.S. in metallurgy preferred. Recent graduate or 2 to 3 years research or development experience acceptable. Position involves fabrication research on joining, rolling, extrusion, casting, and forging of beryllium for aircraft structures and nuclear applications.

SALES—As a technical contact man for Sales, having had non-ferrous experience and some knowledge of metal powders and parts made from metal and ceramic powders.

Send complete resume to—
Personnel Director

The Beryllium Corporation
P.O. Box 1462
Reading, Pennsylvania

WANTED for Assistant Open-Hearth Shop Superintendent on Mexican Border. Junior Melter or higher having 7 years experience or more. Must have operating experience, ability to handle men and must be Mexican. Salary open. Reply to La Consolidada, S.A., P.O. Box 120, Eagle Pass, Texas.

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PHYSICAL METALLURGISTS, for research and development in high temperature materials. Advanced degree and minimum of 3 years experience, including X-ray diffraction, metallographic inspection and experimentation with ultra-high temperature physical properties. Familiarity with powder metallurgical techniques preferred.

Qualified applicants are invited to send resumes and inquiries to Mr. L. R. Stapel.

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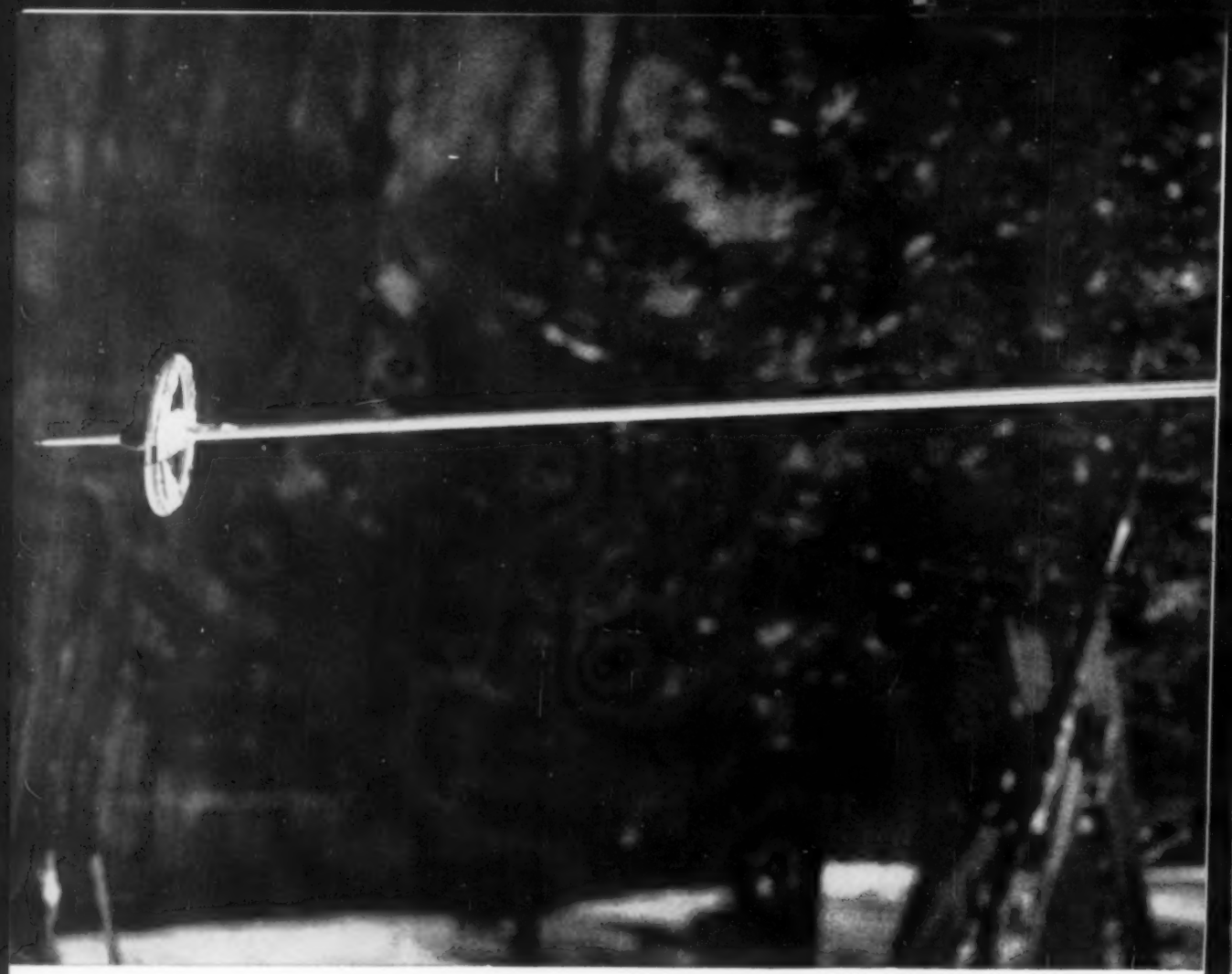


Lightness—There are a few products in this world that you don't want to be light—like pile drivers, dumbbells and paper weights. But generally speaking, every designer strives for the lightest product that will do the job, especially in things like truck trailers and off-highway earthmoving equipment (the lighter the unit, the greater the load capacity) and in structures like a bridge, which has to support itself *and* a roadbed.

Lightness is easy to attain. For instance, you could make a ski pole out of balsa wood, rather than the Stainless shown above, and never know you were holding it. But almost always as we strive for lightness, we also demand a certain amount of stiffness, ductility, strength. More than that, we need a material that can be fabricated on high-speed machinery.

So it's interesting to note that today, in cases where lightness is absolutely vital and *hang the cost*, designers still turn to steel rather than costlier materials when they need low weight and high performance.

When our Explorer I satellite screamed into outer space, it was cased in Stainless Steel. On every high-performance aircraft, the landing gear is made from ultra-strong steel because each single pound shaved from the landing gear assembly saves from 7 to 10 pounds of total aircraft weight, since it reduces the wing area, thrust and fuel required for the specified performance. Today, as we prepare for the first exospheric manned flight, we are completely sheathing the fuselage in steel, because no other available material has a better combination of lightness and high temperature strength.

In new, light-weight bridges, designers automatically think in terms of the new alloy and high strength steels. They're so strong that thinner, lighter sections can be used, and they have the extra atmospheric corrosion resistance necessary.

The new steels should be chosen and fabricated with care, and the final selection should be made by a skilled metallurgist—either on your staff or ours. United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

United States Steel Corporation • American Steel & Wire • Columbia-Geneva Steel • National Tube
Tennessee Coal & Iron • United States Steel Supply • United States Steel Export Company

USS United States Steel

STEELS FOR DESIGN

Lower Left—Problem: Design a trailer to haul more coal and stay within the legal highway weight limit. Solution: Marion Metal Products Company used USS COR-TEN High-Strength Low-Alloy Steel to build a bigger trailer that is lighter because the stronger steel can be used in thinner sections. Payoff: The new units weigh 23% less than the old, have a 50% greater payload, and gross weight is *still* within the legal limit.

Lower Middle—Problem: Build a 40-ton-capacity bottom dump trailer that would have the highest payload-to-weight ratio ever obtained. Solution: Athey Products Corporation designed the unit with USS "T-1" Constructional Alloy Steel which combines a minimum yield strength of 100,000 psi with weldability and remarkable toughness. Payoff: New trailer weighs 11,000 pounds less than conventional construction and hauls payload over 3½ times its own weight.

Lower Right—Problem: Replace 550-bbl. fermentation tanks with new tanks of same capacity but light enough to hang from the ceiling. Solution: Chicago Steel Tank chose Type 304 Stainless Steel and a unique new design utilizing Stainless Steel's strength and formability. Payoff: New tanks weigh only one-fourth as much as the old and have identical capacity.

USS, COR-TEN and "T-1" are registered trademarks

Greater Heat-Treating

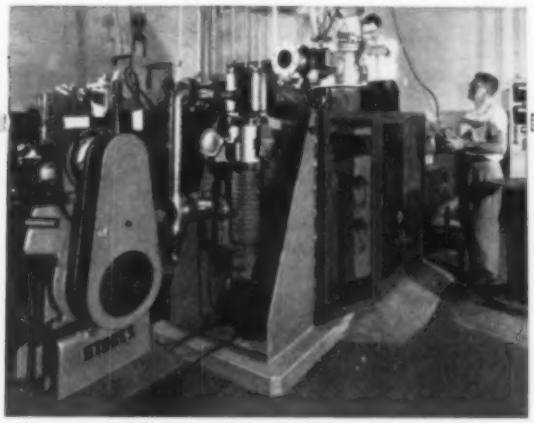
with Stokes Vacuum

Heat-treating processes have taken forward steps and gained new momentum through the advances of vacuum furnace technology. These are but a few examples of industries who now rely on Stokes systems to meet their specific production requirements.

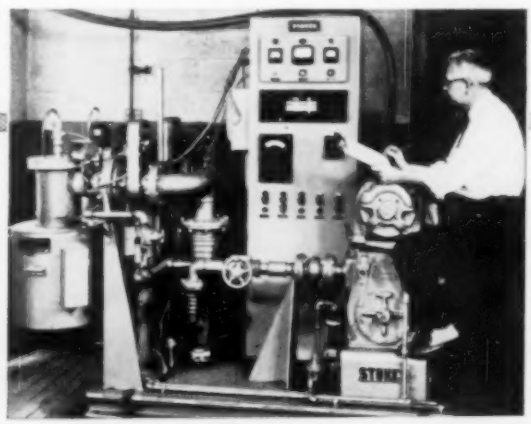
Stokes' extensive design experience and manufacturing facilities combine to make possible these new vacuum heat-treating opportunities. You have a choice of a complete range of types and sizes of furnaces. The systems are offered complete – placing in Stokes a single-source responsibility for performance and reliability.

Stokes offers additional advantages that can contribute to your successful metallurgical programs. Stokes can, for example, deliver a complete turn-key installation – erected, tested and delivered "in operation". Systems also benefit from the use of stock components – facilitating faster delivery. Stokes systems are furnished to do the best possible job at lowest cost to you.

Standard Stokes Vacuum Heat-Treating Furnaces are available for experimental and as full



At The Budd Company's Defense Division, metal components are designed and produced for important and classified nuclear reactor work. Because of the characteristics of the metals used, new procedures were necessary for welding, heat treating and pickling. The Stokes Vacuum Furnace has assumed an important role in these vital processes.



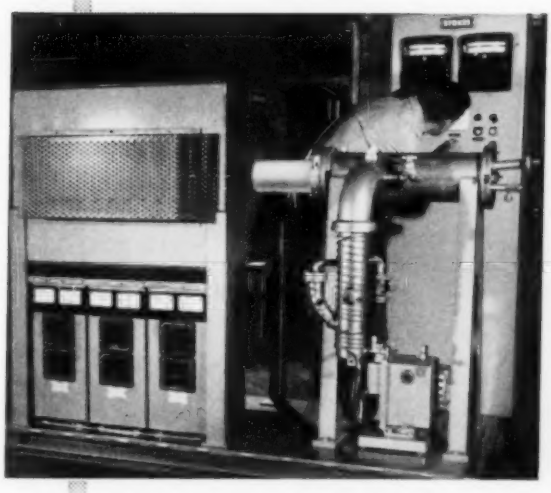
At Associated Spring Corp., Bristol, Connecticut, precision springs finer than a human hair are vacuum heat treated to rigid specifications. Of critical alloys, they require high temperatures. If treated in atmosphere, surface oxidation would be intolerable. A Stokes Vacuum Furnace enables production of springs for even the most delicate instruments.

Progress...

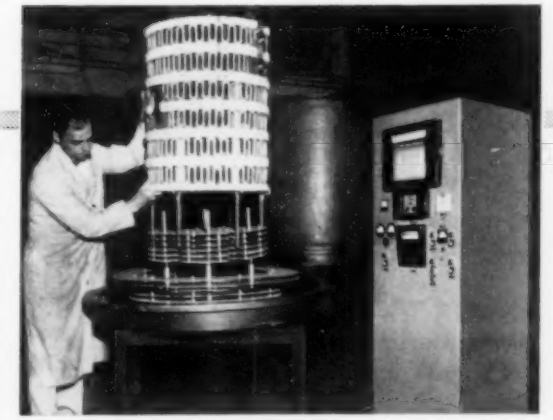
Furnaces

production size systems. Other types are available for melting, refining, casting, sintering, brazing and stream degassing. Special systems can be designed to meet the exact needs of specific operations. All-the-way service, before and after the sale, completes the picture of how well Stokes is equipped to work with you.

You can take full advantage of Stokes' advanced vacuum technology. The Stokes Engineering Advisory Service will assist you in planning and designing a heat treating installation that will best serve your exact requirements. Call Stokes—today.



A resistance-heated, two-zone, high temperature Vacuum Heat-Treat Furnace . . . installed for operation over 2500°F. Available in sizes to 9" I.D., for brazing, out-gassing and heat-treating . . . in both research investigations and small parts production.



A cold wall furnace capable of providing high temperatures at unusually low pressures is one of the most recent developments of Stokes. It is particularly applicable to high temperature solid state processing. Depending on the nature of the application, temperatures up to 2000°C are attainable at sub-micron pressure. Customer built for specific requirements, these furnaces are offered in a wide range of sizes, for research or production service.

In addition, Stokes offers complete laboratory facilities and technical assistance for investigation of commercial heat treating applications where highest temperatures are necessary.

Vacuum Equipment Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.

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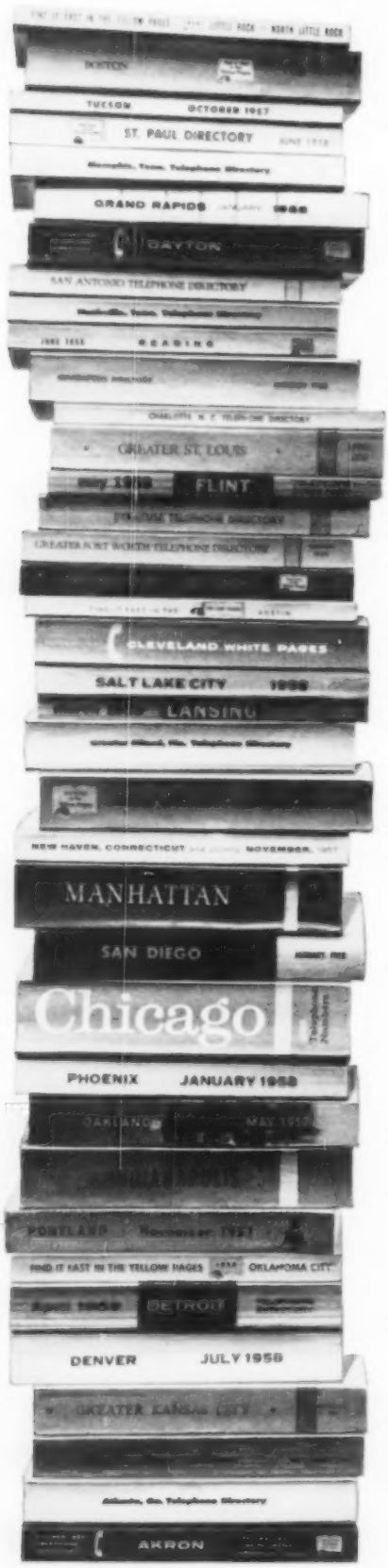

1 in 35,000,000

How the telephone switching system sorts numbers in seconds

When you dial out of town, the telephone switching system performs an amazing feat. It sorts out the one other number in 35 million you want, and connects you to it in seconds. The other telephone may be thousands of miles away.

Bell Laboratories engineers endowed this great switching network with almost superhuman capabilities. As you dial, the machine listens, remembers, figures out the best route, makes connections, alerts, reports, even corrects itself. If it detects trouble on the way, it files a report, then chooses other circuits and goes on to complete your call. All you are aware of is the end product—the completed call.

Yet at Bell Telephone Laboratories, switching engineers see the present system as only a beginning. Ahead they see—and are developing—new systems vastly more flexible and capable than today's. Nowhere in telephone technology is the challenge greater. Nowhere are dreams coming true faster.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

These Bell Telephone System directories list some of the 35,000,000 telephones now linked by the Direct Distance Dialing system developed at Bell Laboratories. In seconds, this unique machine sorts out and connects you with precisely the number you want.

the new Leitz **MICRO-METALLOGRAPH**

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Availability of a Le Chatelier type LEITZ MICRO-METALLOGRAPH has been eagerly awaited by industrial scientific laboratories. With this new instrument, precise details of metallurgical specimens may be viewed simultaneously on the 30" projection screen as well as through the binocular observation tube. The newly-developed, powerful XENON lamp provides ample illumination to permit observation in a normally lighted room. Photomicrography of specimens is quickly and easily accomplished with pre-aligned 5" x 7" camera or, if desired, a Polaroid-Land 4" x 5" camera back. Engineered specifically to meet the needs of the modern, metal working industry the new LEITZ MICRO-METALLOGRAPH "sets a new standard for metallurgical observations."

- Inverted microscope stand with mechanical stage, coarse and fine focusing
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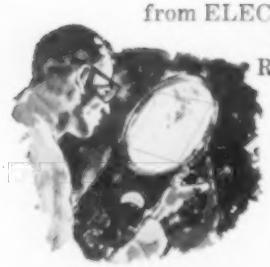

COLUMBIUM for the High Temperature Age

COLUMBIUM METAL is considered an excellent base for an alloy series which will establish new thermal limits. The qualities of this extraordinary refractory metal – medium density, high strength under conditions of extreme heat, resistance to radiation damage, and low "neutron-capture" cross-section – have already resulted in its use for some nuclear applications and indicate potentialities in the electronics field. ELECTROMET's process results in columbium melting stock of the highest purity available commercially. And the technical staff at ELECTROMET is ready to advise you on *any* phase of development or application. The coupon will bring additional data.

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News of EDUCATION

METAL JOINING COURSE

Two courses on Metal Joining designed to be of practical help to high school graduates who are now employed by industry, will be offered at the Industries Training School, **Stevens Institute of Technology**, New Jersey, during the 1958-59 academic year.

Metal Joining, Light Assemblies, and *Metal Joining, Heavy Assemblies*, will be given during the spring semester, on Tuesday and Thursday evenings respectively, begining February 9, 1959.

The course on light assemblies will give particular emphasis to soldering, brazing and welding, resistance welding, and adhesive bonding. *Metal Joining, Heavy Assemblies*, will also contain material on all joining processes, but will give particular emphasis to the arc welding processes.

The courses are on a college level, but may not be applied toward a college degree. Further information may be obtained from the *Information Center, American Welding Society, 33 W. 29th Street, New York 18, N. Y.*

DIE CASTING PROGRAM

A new die casting program was established at **Pennsylvania State University**, sponsored by the national American Die Casting Institute (ADCI), and its Eastern Regional Group. The program includes two scholarships, and a cash prize award system.

It is hoped by the ADCI, that the program, which is being extended to other engineering schools as quickly as possible, will attract new engineering talent into the custom die casting industry.

BOOKS

U. S. Department of Commerce Publications

Request publications from:
Office of Technical Publications
U. S. Dept. of Commerce
Washington 25, D. C.

DP-214 *Erosion of Aluminum*, 20¢, 16 pp., 1957.

HW-43031 *Ultrasonically Bond Testing Hanford Fuel Elements*, 35¢, 30 pp., 1956.

KAPL-1380 *Preparation of Spherical Uranium Powder by Reduction of Uranium Trioxide with Calcium*, 40¢, 29 pp., 1955.

KAPL-1518 *Uranium Preparation by Electrolytic Reduction of Oxides*, 40¢, 29 pp., 1956.

KAPL-1692 *The Behavior of Representative Fission Products and Plutonium in the KAPL Electrorefining Process and a Review of the Status of the Process*, 30¢, 34 pp., 1957.

KAPL-1726 *Development of Zircaloy-Clad, Discrete Burnable Poison Elements for S3G/S4G*, 25¢, 24 pp., 1957.

KAPL-1726 *Corrosion of Aluminum in High Temperature Water, II. Application of Infrared Spectra to Corrosion Studies*, 20¢, 16 pp., 1957.

NAA-SR-36 *Studies in the Impregnation of Graphite with Uranium*, 35¢, 25 pp., 1950.

NAA-SR-1867 *Effect of Sodium on the Mechanical Properties of Zirconium*, 30¢, 39 pp., 1957.

NAA-SR-1926 *Germinative Grain Growth Characteristics of Zirconium*, 25¢, 25 pp., 1957.

NMI-1176 *Quarterly Progress Report for the Period Jan. 1, 1957 through Mar. 1957*, Nuclear Metals Inc., 25¢, 26 pp., 1957.

ORNL-1774 *Diffusion Characteristics of Thorium and Aluminum*, 40¢, 41 pp., 1954.

RMO-2801 *Recovery of Uranium Values from Ore and Concentrate Samples, Progress Report No. 1*, 60¢, 110 pp., 1954.

RMO-2805 *Recovery of Uranium Values from Ore and Concentrate Samples, Colorado Primary Ores, Progress Report No. 5*, 45¢, 71 pp., 1955.

SEP-179 *Zone Melting of Uranium*, 20¢, 20 pp., 1955.

TID-10070 *A Review of the Metallic Fuel Element Development Program*, 25¢, 15 pp., 1953.

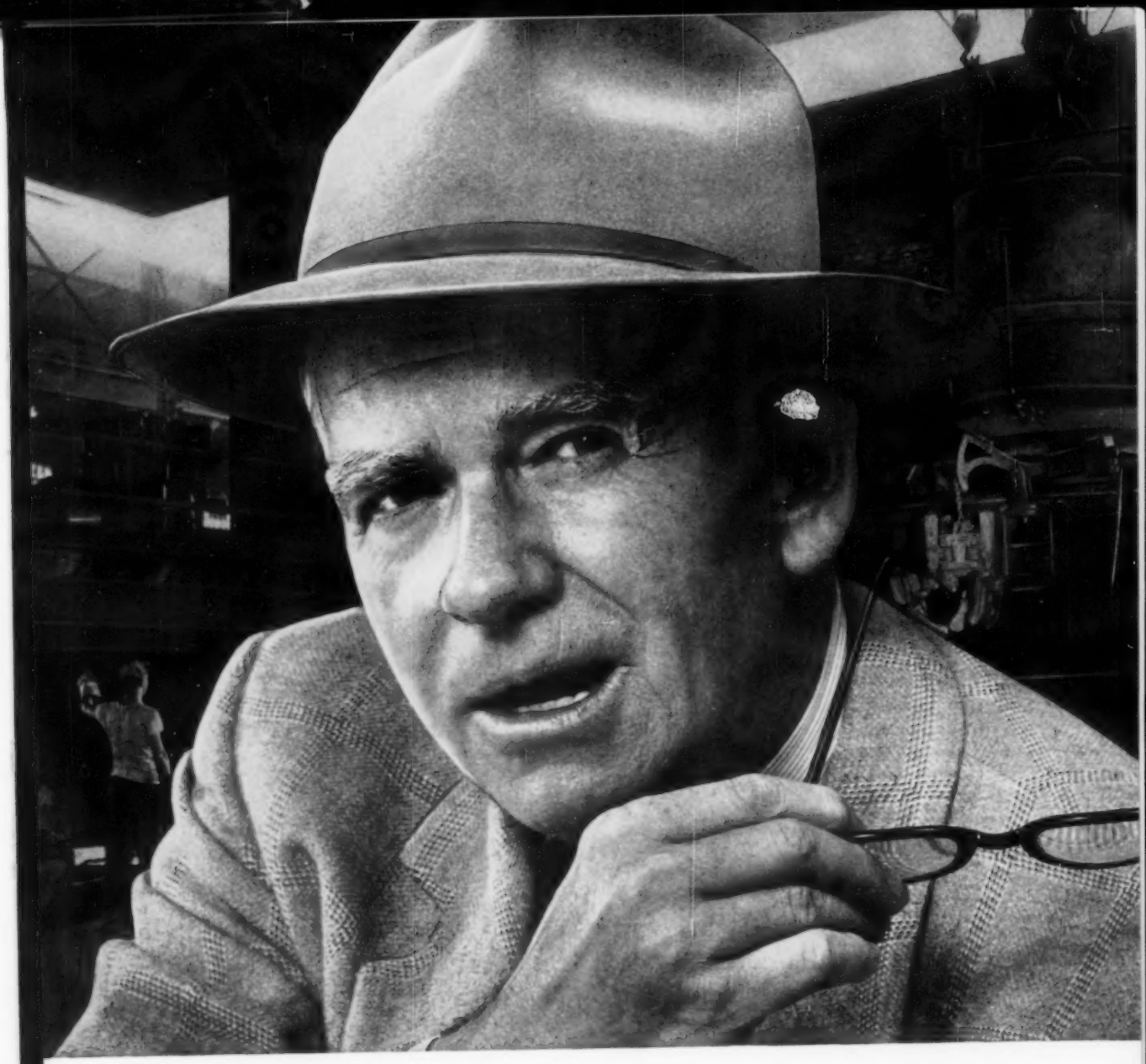
TID-10099 *Fundamental and Applied Research and Development in Metallurgy, Progress Report for April 1955*, 25¢, 9 pp., 1955.

WAPD-127 *Development and Properties of Uranium-Base Alloys Corrosion Resistant in High Temperature Water, Part I, Alloys Without Protective Cladding*, 85¢, 158 pp., 1955.

WAPD-167 *The Effects of Irradiation Cycling on Pressurized Water Reactor Blanket Fuel Elements*, 50¢, 37 pp., 1957.

WAPD-PWR-PMN-446 (Portions delated) *Resume of Uranium Oxide Data, VI*, 45¢, 77 pp., 1956.

WAPD-PWR-PMM-429 *Resume of Uranium Oxide Data—V*, 45¢, 72 pp., 1956.



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- **A base charge for stainless steels.**
- **Final additions for aircraft, bearing, and tool steels.**
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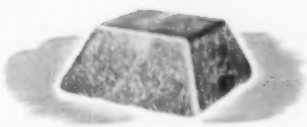

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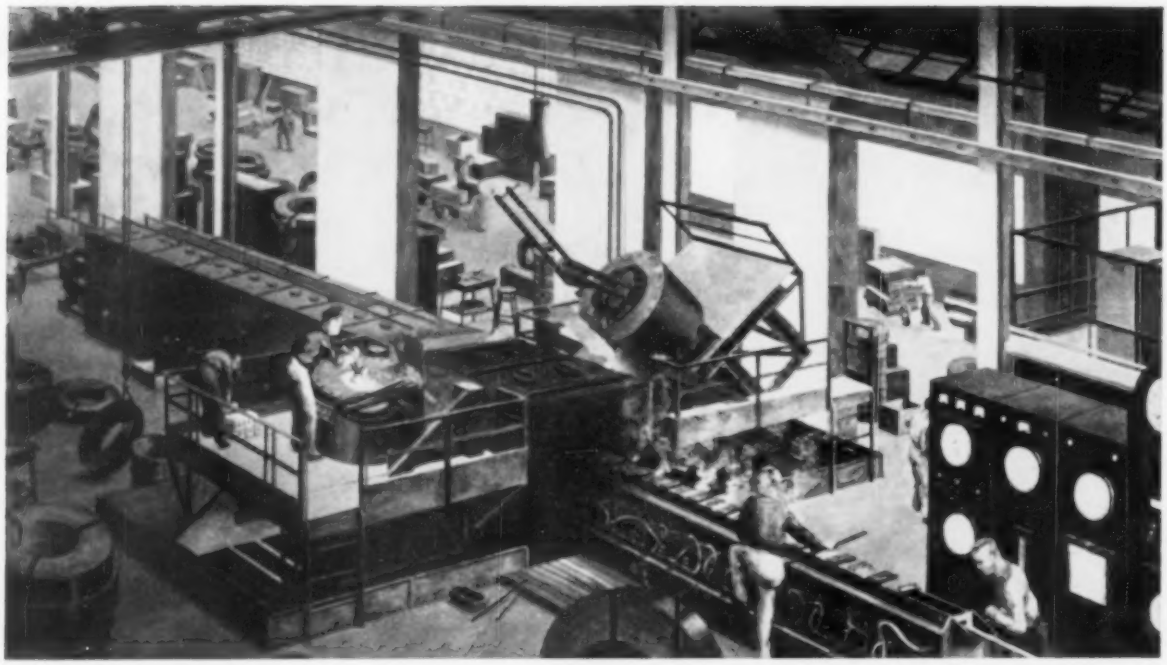

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The heavy duty 60 cycle inductor developed by AJAX and pioneered by CLEVITE will attain a lining life of one year with bronzes of substantial lead content. Electromagnetic stirring assures uniform alloy and close temperature control. Compared to externally fired equipment, metal loss savings run into many thousands of dollars per year. Recently, several large producers of leaded bronze castings converted their foundries entirely to 60 CYCLE INDUCTION MELTING.

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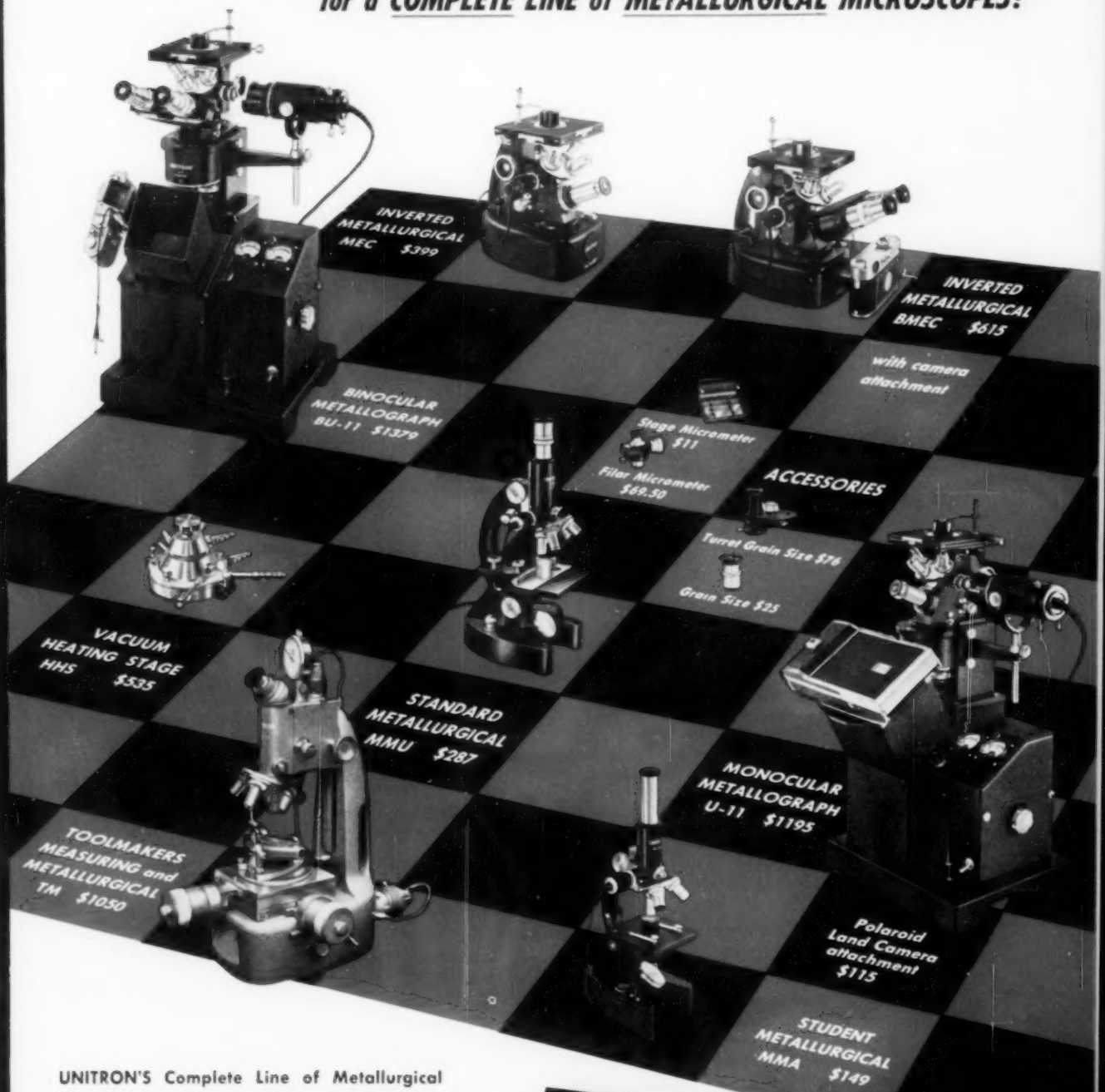

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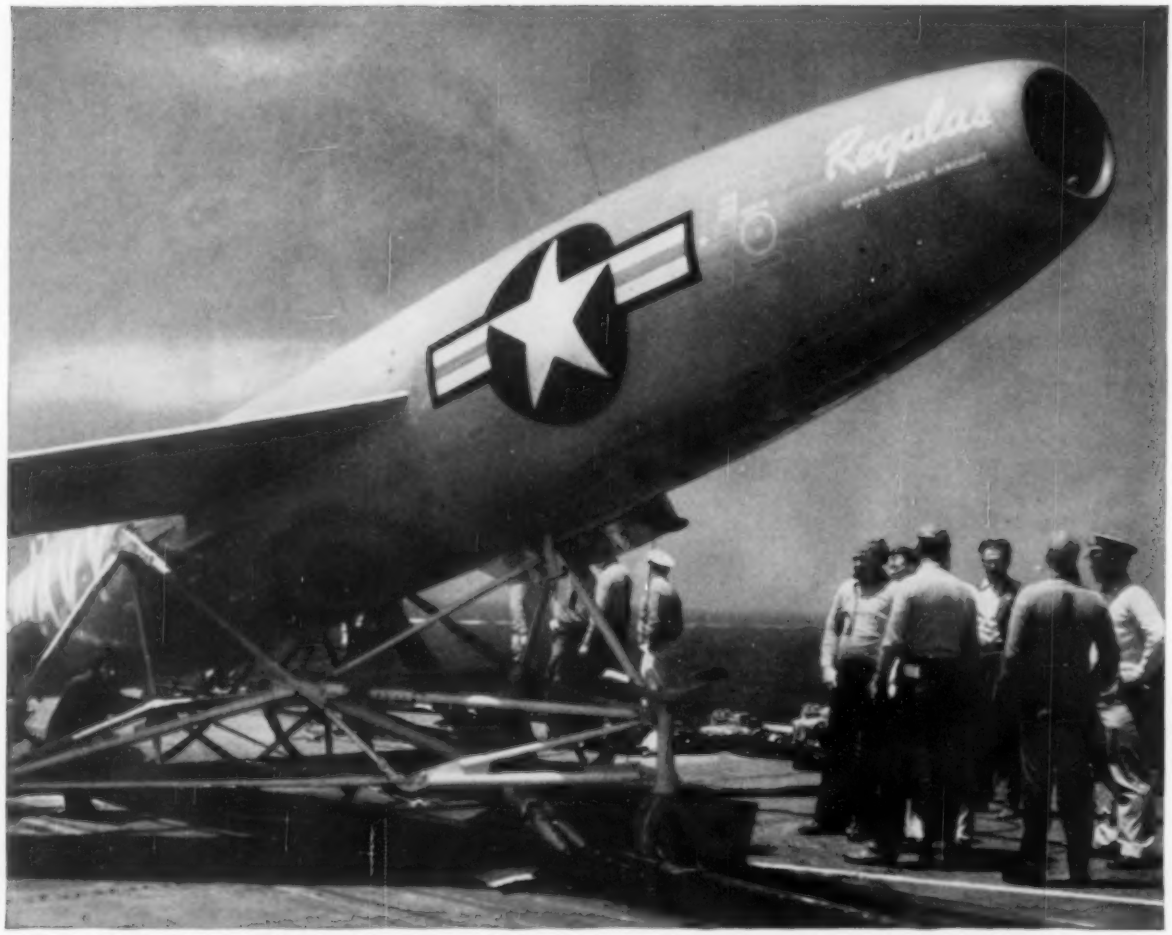

Checking Regulus I surface-to-surface missile prior to launching from experimental cart. For the use of Ni-Cr-Mo steel castings in the launching cart, Chance Vought was judged a National Award Winner in the Third Product Development Contest conducted by the Steel Founders' Society of America.

How castings of 4330 nickel-alloyed steel help boost a missile up, push assembly cost down

20-Ni-Cr-Mo steel castings replace 73 detail parts, eliminate 300 hardware items in new launching cart

Regulus I, made by Chance Vought, is normally boosted skyward from a rail launcher. The Navy, however, wanted a more economical launching technique that would utilize a carrier's powerful catapults . . . that would also simplify handling of the missile aboard ship.

The answer was the expendable catapult cart you see above.

The carts, also made by Chance Vought, are assembled with 20 cast 4330 steel cluster joints welded to tubing of the same material. These castings replaced 73 detail parts required in the plate-type fittings of the experimental units used to prove the idea. They also eliminated 300 hardware items, such as nuts and bolts. Assembly is easier, and far more economical.

Why Ni-Cr-Mo steel for the castings? The 4330 composition of 1.8% Ni .65% Cr. .25% Mo heat treated to 125,000 and 150,000 psi gives these castings the combination of high strength and great toughness needed to stand up to the tremendous shock of take off.

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Heat Treatable Titanium Alloys

In recent weeks, announcements have been made of new titanium alloys which can easily be worked and later heat treated to high strength.

Mallory-Sharon Metals Corp. has three new alloys. One, containing 2.5 pct Al and 16 pct V, has a yield strength below 65,000 psi, but simple aging treatment increases tensile strength to 200,000 psi. A second alloy containing 8 pct Al, 2 pct Cb, and 1 pct Ta, is easily arc welded, yet it retains high tensile strength and good ductility. A third alloy is composed of 3 pct Al and 2.5 pct Va; it is designed for high strength tubing because of its good welding properties and exceptionally high resistance to corrosion.

Crucible Steel Co. of America has three alloys capable of withstanding temperatures up to 1400°F. Exact compositions have not been disclosed, but it is known that they contain vanadium, chromium, and aluminum. They are capable of being formed in a soft condition and then easily strengthened by thermal aging. One is the first heat-treatable all-β titanium alloy.

Titanium Metals Corp. of America has developed a radically new furnace in which titanium sheet is heated to 1600°F through a quick, powerful jolt of electricity. The red hot metal is rapidly water quenched.TMCA's leading heat-treatable sheet alloy contains 4 pct Al, 3 pct Mo, and 1 pct Va; it has a maximum tensile strength of 190,000 psi. This firm has developed methods of heat-treating the widely used 6 pct Al 4 pct Va alloy to increase strength by 20 pct.

High-purity silicon

At Brevard, N. C., Du Pont has recently inaugurated its new high-purity silicon plant. Developed as a result of Du Pont's research program, commercial silicon was first produced during World War II for radar equipment. Peacetime uses are largely as semiconductors for transistors . . . In France, the annual report of the Pechiney firm reports the production of 100 kg per month of high-purity silicon at its Calypso plant.

Anaconda forms engineering subsidiary

The Anaconda Co. is broadening its corporate engineering structure with the formation of a new subsidiary, Anaconda-Jurden Associates, Inc. This will, however, not be a new activity for Anaconda, since there has been, for some time, an extensive engineering department which offers complete service in design and construction of large-size industrial plants. This includes not only plants erected for Anaconda, but also the taconite plant of Erie Mining Co. and a number of installations for Phelps Dodge Corp. Present activities include the $110 million copper project for Andes Copper Mining Co. in northern Chile, as well as the $40 million Anaconda aluminum fabrication plant at Terre Haute, Ind.

Plutonium reactor fuel

For the first time a nuclear reactor is producing substantial amounts of power from man-made plutonium. According to a recent AEC announcement, the Arc, Idaho, materials-testing reactor, operating on a plutonium fuel core, has been producing power at the 500 kw level and is expected to have a future output level of 30,000 kw. Plutonium is superior to uranium as a reactor fuel, but it is extremely poisonous and hard to tool.

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PROJECT SHERWOOD—THE U.S. PROGRAM IN CONTROLLED FUSION
By Amasa S. Bishop, U.S. Atomic Energy Commission
The first detailed account of "Project Sherwood"—the search for means of harnessing the energy of thermonuclear reactions. Written for the thoughtful layman as well as for scientists and engineers, this book parallels the historic "Smyth Report." **228 pp, 53 illus, 1958—$5.75**

U.S. RESEARCH REACTOR OPERATION AND USE
Edited by Joel W. Chastain, Jr., Battelle Memorial Institute
Describes the basic types of research reactors, and the uses for which each is best suited; also discusses operating, administrative, legal and cost problems. **384 pp, 181 illus, 1958—$7.50**

RADIATION BIOLOGY AND MEDICINE: Selected Reviews in the Life Sciences
Edited by Walter D. Claus, U.S. Atomic Energy Commission
More than 50 distinguished authors review advances in the uses and effects of nuclear radiation in biology, medicine, and agriculture. Among the topics covered are radioisotopes in medicine and agriculture, mutations, permissible dosages, and mathematical biology. **968 pp, 198 illus, 1958—$11.50**

URANIUM ORE PROCESSING
Edited by J. W. Clegg and D. D. Foley, Battelle Memorial Institute
For the first time in book form, a condensed but essentially complete description of current practices in the winning of uranium from its ores. **450 pp, 118 illus, 1958—$7.50**

THORIUM PRODUCTION TECHNOLOGY
By F. L. Cuthbert, National Lead Company of Ohio
Contains virtually all of the information currently available on thorium production technology. The organization of the book follows the natural production flow from minerals in the ground to the fabricated slug. **320 pp, 84 illus, 1958—$6.50**

SOLID FUEL REACTORS
By J. R. Dietrich and W. H. Zinn, General Nuclear Engineering Corporation
Reviews the basic concepts, present state of development, and technical and economic outlooks of five projected solid fuel nuclear power reactor types; fast-neutron power breeders, heavy-water reactors, gas-cooled reactors, organic moderated and cooled reactors, and a thermal reactor for recycling plutonium. **864 pp, 385 illus, 1958—$10.75**

PHYSICAL METALLURGY OF URANIUM
By A. N. Holden, General Electric Company, Vallecitos Atomic Laboratory
A comprehensive and unified treatment which places emphasis upon interpretation in terms of fundamental properties and mechanisms, and relates the metallurgical behavior of uranium to that of other metals. **272 pp, 190 illus, 1958—$5.75**

BOILING WATER REACTORS
By Andrew W. Kramer, Editor, Atomics, and formerly Editor, Power Engineering
This valuable reference work on the history and technology of boiling water reactors includes detailed descriptions of the Experimental Boiling Water Reactor (EBWR), the Vallecitos reactor, and the various BORAX experiments. **592 pp, 292 illus, 1958—$8.50**

FLUID FUEL REACTORS
Edited by J. A. Lane and H. G. MacPherson, Oak Ridge National Laboratory, and Frank Maslan, Brookhaven National Laboratory
A thorough treatment of three basic types of fluid fuel reactors; aqueous homogeneous reactors, fused salt systems, and liquid metal fuel reactors. **1008 pp, 338 illus, 1958—$11.50**

THE TRANSURANIUM ELEMENTS
By Glenn T. Seaborg, University of California
This book provides a complete summary of the chemical and nuclear properties of the known synthetic transuranium elements, as well as the prospects for future elements. **354 pp, 73 illus, 1958—$7.00**

SODIUM GRAPHITE REACTORS
By Chauncey Starr and R. W. Dickinson, Atomics International
A unified and coherent presentation of sodium graphite reactor technology. While emphasis has been placed on the design and development of the Sodium Reactor Experiment (SRE), the authors have wherever possible included information applicable to sodium graphite systems and, in many cases, to reactor design in general. **304 pp, 99 illus, 1958—$6.50**

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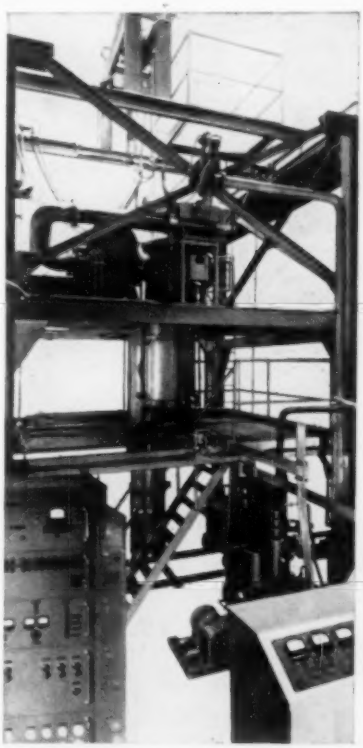

Ingots of 16" diameter can be processed in this Model VA-L 600 sh Heraeus furnace.

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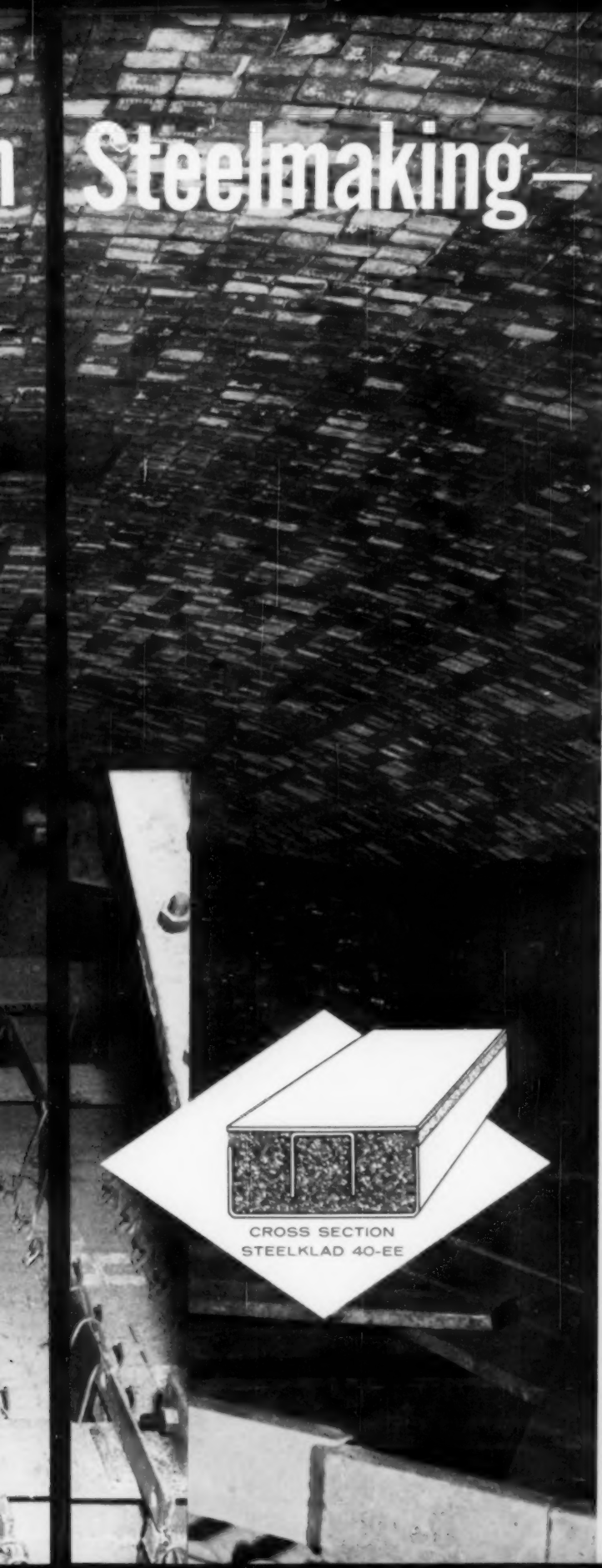

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the roof of the "All-Basic" open hearth furnaces now breaking production records.

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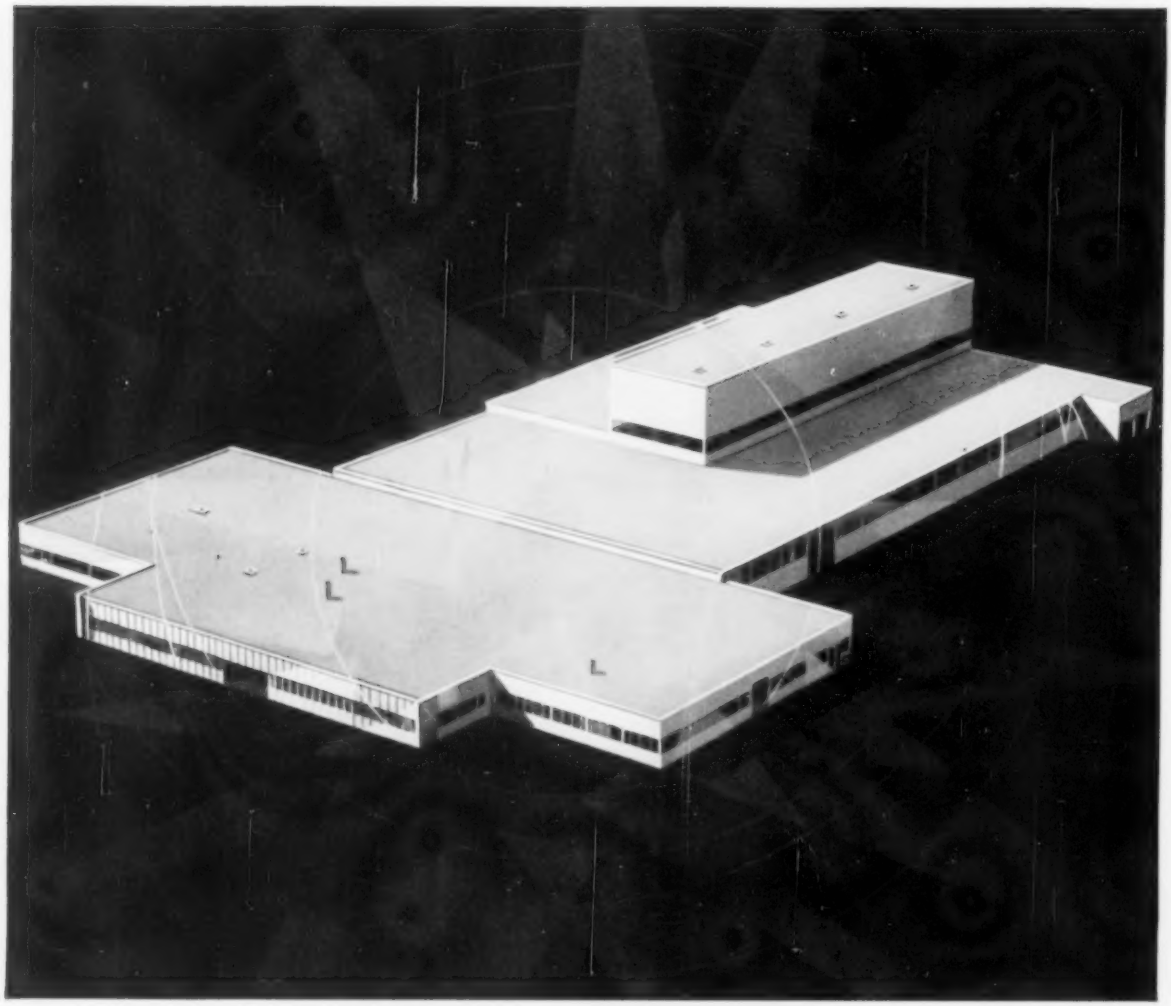
(*At left*) A new roof of "STEELKLAD 40-EE" converts this open hearth furnace to "All-Basic" construction, and permits vastly increased production, at lower cost.

Metals Division of Kelsey-Hayes expands in New Hartford . . . to produce vacuum induction metals for all industry



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A SALUTE TO THE METALLURGISTS OF BELGIUM

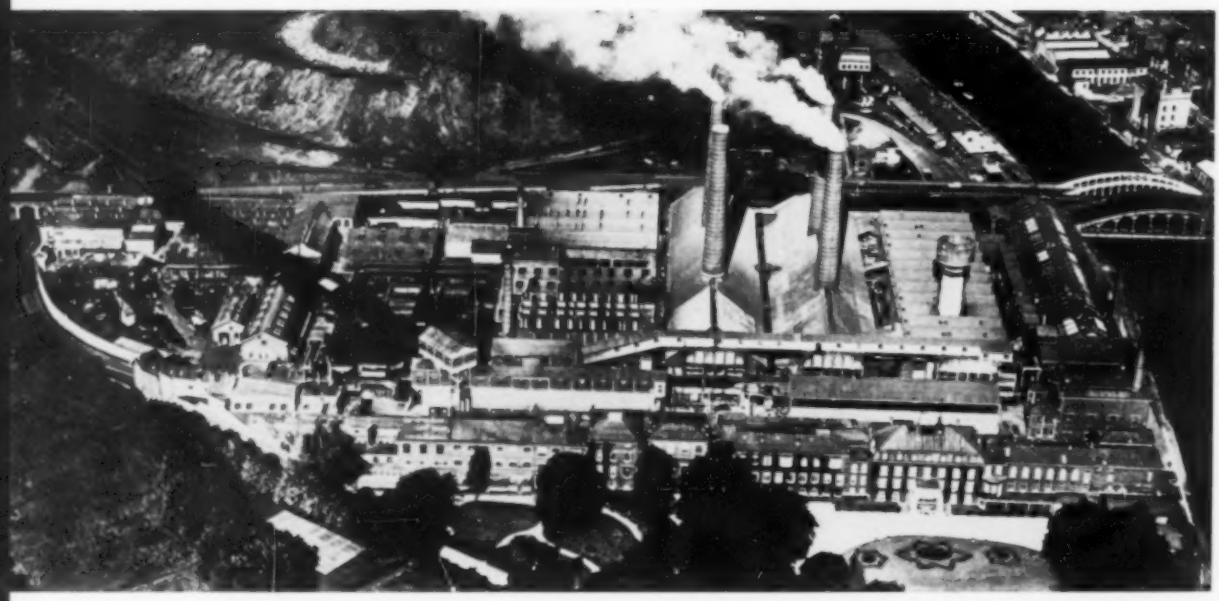
A small country with only 9 million people, hence a relatively small internal market, with its present-day ferrous and nonferrous mineral deposits almost nonexistent, Belgium's long metalworking tradition has, nevertheless, carved a prominent place for,

Metallurgy in Belgium

The ferrous metals industry ranks eighth in world production and, together with its economic partner, Luxembourg, is the world's largest steel exporter. Belgium is also moving ahead on the technological front, and its National Metallurgical Research Center—CNRM—has perfected techniques for the production of high-quality basic-bessemer steel which is the backbone of its ferrous production.

The nonferrous metals industry is probably the most important in Europe and, on a world-wide basis ranks first in cobalt, second in zinc, and third in copper. Its perfection of methods of radium production is history, as is its more recent production of uranium. Today, in the technological forefront are commercial techniques for the production of such metals as germanium and high-purity silicon.

The Belgian metallurgist can look with pride on his accomplishments.



Angleur zinc retort plant of the Société de la Vieille Montagne.

NONFERROUS METALS IN BELGIUM

A short summary compiled by

Edmont Hainne, Secretary General,

Societe Royale Belge des Ingenieurs et des Industriels

Fig. 1—The bronze baptismal font at the church of St. Barthélemy in Liège, Belgian was cast in the 1115 as a work of Regnier de Huy. Courtesy J. Rasquinet of S.A. Usines à Cuivre et à Zinc de Liège.

Fig. 2—The *Dianderie* is a work of the copper beaters of the Meuse valley of Belgian, dating from 1554. Courtesy, J. Rasquinet, of the S.A. des Usines à Cuivre et à Zinc de Liège.

From a metalworking tradition dating back to the copper-beaters of the 15th Century, a country almost totally lacking in nonferrous mineral resources has become one of the world's leading metal producers.

THE Belgian metalworking industry, whose origins date far back in history, has traditionally been situated in the valley of the Meuse river. It was there that the casting of nonferrous metals reached a fine art as early as the 12th century. A fine example of such an early bronze casting is the baptismal font at the church of St. Barthélemy in Liège. Shown in Fig. 1, it dates from the year 1115. This remarkable epoch gave way to the copper beaters of the 15th and 16th centuries; an example of their fine workmanship is shown in Fig. 2.

Zinc's early development

Present day extractive metallurgy, as distinguished from metalworking, had its roots in zinc; naturally so, since this was the only nonferrous metal whose ores were found in Belgium. The deposits, already worked in the 15th century, were largely calamine, which was used for the production of brass for the copper beaters of the Meuse valley.

In 1806, a concession to the Moresnet deposit was granted to a chemist from Liège by the name of Doney, who evolved a process for the reduction of calamine to the metallic state. Beginning in 1808, he produced zinc in the form of ingots, sheet, and wire. The operation was not financially successful, but after his death in 1818 several firms in the Liège region entered into the production of zinc on an industrial scale, with lead and zinc as byproducts.

Since then, in spite of the rapid exhaustion of Belgian zinc deposits, the industry continued to expand. It is based on imported raw materials which are volitalized in retorts made of the exceptionally fine clays of Liège.

Influence of the Congo

Zinc, then was the Belgian nonferrous metals industry until the opening of the mineral-rich Congo and the foundation of the Union Minière du Haut-Katanga in 1906 to exploit these resources. Methods to treat these ores were largely developed by the Belgian chemist, Joseph Leemans, and this led to the establishment in 1919 of the Société Général Metallurgique de Hoboken, a metallurgical complex including lead, copper, and tin smelters and a precious metals refinery at Hoboken, near Antwerp; —Fig. 3—an electrolytic copper refinery with cobalt, nickel, and radium units at Olen, and an arsenical products plant at Reppel.

Present position[1]

The result of this combination of a metalworking tradition, the early established zinc industry, and the more recently developed copper-cobalt-lead industries is the blossoming of Belgium into one of the world's leading nonferrous metals producers. For this group of metals as a whole (excepting aluminum) Belgium together with the Congo ranks second in the world (excluding the USSR), and, first in cobalt, second in zinc, and third in copper.

The Belgian market itself is hardly able to absorb a large part of this production, and must, in fact, export some two thirds of its overall production. So, quite naturally Belgium ranks in first place as an exporter of nonferrous metals as a whole, and first in cobalt, second in copper and zinc, and third in lead and tin.

[1] Edouard Thimmesch: l' Industrie Belge des Metaux Non Ferreux, *Industrie*, No. 3, March, 1958.

Fig. 3—View of the lower plant of the Hoboken plant of the Société Generale Métallurgique de Hoboken in Belgium.

IRON AND STEEL IN BELGIUM

by Pierre van der Rest

Above . . . The Ougree-Seraing plants of S.A. Cockerill-Ougree, near Liege, Belgium's largest steel plant. Below . . . The 150-ton electric arc furnace at the Fabrique de Fer de Charleroi is Europe's largest.

With its origin in ancient times, the Belgian iron and steel industry now ranks eighth in world production and, together with Luxembourg, is the largest steel exporter.

PIERRE VAN DER REST is President of the Groupement des Hauts-Fourneaux et Aciéries Belges, Bruxelles.

FERROUS metallurgy got an early start in the old Roman province of Belgian Gaule where the population acquired a great aptitude in the art of ironmaking, which was widely acclaimed. One still finds in Belgian numerous traces of this early activity, including furnaces, slag heaps, etc. The birth of this ferrous industry was favored by the then bountiful resources of Belgium: abundant ore deposits in numerous regions, almost inexhaustible forest reserves, and copious water supplies. These natural resources, plus the country's very advantageous geographic position, and its developing manufacturing industries, have played an important role in building the iron and steel industry throughout the centuries.

Technical pioneer

The techniques employed by the Belgian forge masters were in the forefront of the early progress of the industry. It was in Belgium, at the end of the 14th century, that the indirect method of making iron by means of the pig-iron process was developed. This method, which spread rapidly throughout Europe, was known as the *Wallonne* method, after that part of the country which still houses the Belgian steel industry. Another development, and a corollary of the first, was that of the melting furnace, ancestor of the modern blast furnace, and replacing the old sponge furnaces. Still later, in 1824, the first coke blast furnace on the European continent was blown-in at the Cockerill plant at Seraing, near Liège.

Appearance of thomas steelmaking

Belgian iron production continued to expand on the basis of local ores and coal deposits, which were then the most important in Europe. The decisive factor in the development of the steel industry was the discovery and first application of the thomas (basic-bessemer) process in 1870 which rendered possible the utilization of the rich deposits of high-phosphorus ore in the Lorraine basin of France. Belgian plants thus found a new raw-material base at a distance relatively short. This was fortunate, since local ore deposits were being rapidly depleted. Aided by this new stimulant, Belgian production soared from 600,000 metric tons of iron and steel in 1880, to 1,100,000 tons in 1900, and 2,400,000 in 1913.

Export orientation

The greatest part of this expanded steel production was destined for export, since domestic markets could absorb only small quantities. The geographic position of the country favored international commerce, and the proximity of the port of Antwerp gave the steel industry direct access to overseas markets. Furthermore, in that period of free exchange, commerce with neighboring states was able to develop naturally.

Since that time it has been the evolution of world steel markets which has determined the expansion of the Belgian steel industry. Between the two world wars, maximum production was attained in 1929 with 4.1 million metric tons of crude steel. In recent years, 1956-1957, production reached 6.2 million metric tons, which places Belgium in eighth place among world producers.

Today, the Belgian steel industry is still centralized in the southern part of the country, along the valley of the Meuse in Liège and the province of Hainaut. There production is concentrated in nine integrated plants. In addition, there are about a dozen rerolling mills.

Converter techniques improved

The raw material basis of the Belgian steel industry has favored the thomas steelmaking process, and it accounts for more than 85 pct of the country's crude steel production. This has naturally created a particular interest by Belgian metallurgists in the perfection of the converter technique. Many original processes have been developed, and oxygen blowing is now used on more than 50 pct of the thomas steel produced.

Developments are also taking place in the domain of electric furnace steel. In Charleroi, the Fabrique de Fer has recently installed and put into operation a 150-ton Lectromelt arc furnace, which is the largest in Europe.

Recent capital investments

During the last 6 years, Belgian steel plants have undertaken an intensive investment program. New blast furnaces were built, and old furnaces were reconstructed on the basis of greater dimensions. Other important new installations were two semi-continuous wide strip mills with corresponding cold reduction units.

Important new projects still figure in the coming years, representing an investment of some $50 million a year. These will include rolling mills for structural shapes and heavy plates, as well as the installation of sintering plants.

Raw material basis

Belgian iron ore mines, formerly important, are close to total exhaustion and can not furnish more than 100,000 tons a year. Thus, Lorraine and Luxembourg deposits now constitute the principal base of supply, but in recent years the industry has also been receiving increasing amounts of Swedish ore.

Deposits of coal, which were a decisive factor in the development of the ferrous metals industry in Belgium, have in many cases, become difficult to work. Coal mines in the southern part of the country, many of which have been in operation for more than a century, suffer from generally low productivity. On the other hand, in northern Belgium there is a more recently opened coal mining region which holds some promise of future expansion.

Independent of these difficulties, Belgian coke producers are always interested in importing coal because of price, quality, and availability. Conditions in recent years have rendered indispensible the importation of considerable quantities of American coal.

Producing for world markets

Importing a large quantity of raw materials and fundamentally oriented toward export, it was natural for the Belgian iron and steel industry to welcome the concept of the European Coal and Steel Community from the very beginning. But the creation of the Community has not diminished overseas interest, where the major markets lie. Today, Belgium, together with Luxembourg, to which it is tied in an economic union, is the principal supplier of steel to the world market.

BELGIUM'S METALLURGICAL RESEARCH CENTER

Having its roots in a research unit established by the University of Liège and a similar unit organized by a Charleroi steel firm, the Centre National de Recherches Métallurgiques—CNRM—was established in 1947 to combine these two centers. Today it is one of Europe's important metallurgical research organizations.

Translated from reports

by Pierre Coheur and J. Zaeytydt

UNITING two metallurgical research centers in Belgium's steelmaking centers of Liège and Charleroi, the Centre National de Recherches Métallurgiques—CNRM—was founded as a nonprofit organization in 1947. While the two regional research centers ceased to exist as entities themselves, each has retained its own laboratory as well as a high degree of autonomy in order to preserve close links with industry.

Participation in CNRM is open to all ferrous and nonferrous metal producers and fabricators in Belgium and Luxembourg. Administrative matters for each section are controlled by a committee composed of the heads of participating regional metallurgical plants, and the overall administration of CNRM is directed by a Council of Administration composed of delegates from the two regional committees.

The research effort of each center is guided by a technical committee composed of the chiefs of industrial metallurgical laboratories. In research work which is actually conducted in plants, these committees have recourse to specially constituted commissions uniting specialists from academic and industrial spheres. These commissions determine not only the means to attain the desired research goal, but also assume responsibility for the conduct of the work. Technical liaison between the Liège and Hainaut sections of CNRM is achieved through a Coordinating Committee.

CNRM is characterized by close collaboration with universities and metallurgical firms in order to carry out its laboratory program. For research on new processes and techniques, close relations with plants and industrial specialists is essential.

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Opposite, l'Abbaye du Val Benoit, headquarters of CNRM in Liege, Belgium. Above, laboratory for examining elevated-temperature creep properties.

Such close contacts permit a maximum economy in personnel, space, time, and money. Thus, in spite of its limited personnel and budget, CNRM has been able to carry forward important research projects in a minimum length of time.

Liege section

The origin and operations of the Liège section of CNRM are closely connected with the University of Liège, which has one of the most important metallurgical colleges in Europe. This is the center of a major steel-producing basin as well as the center of the zinc and metalworking industries. The section is only a short distance from the Luxembourg steel plants, which it also services.

The Liège section of CNRM is housed in the lovely Abbaye du Val-Benoit, which was constructed in the year 1223, but almost completely destroyed during World War II. Since that time the buildings have been restored to their original exterior appearance with the 3500 sq m interior designed for laboratories and offices.

The Center does not possess laboratories for ordinary chemical analyses or for the classical determination of the physical properties of metals. Such work is carried out at local university or industrial laboratories, thereby allowing the work of the section to be carried out with a total force of only 100 persons, 30 of whom are engineers.

Laboratory research

The Liège section of CNRM is well equipped for the study of metal physics; it has three machines for direct spectral analysis, one of which works under vacuum and can be used for the determination of metalloids. There are a dozen pieces of X-ray equipment for quantative determination and molecular analysis. The section possesses two electron microscopes and an electron diffractograph. Other installations include gas-analysis equipment, a mechanical testing laboratory, and a creep- and hot-rupture laboratory. Some of the highlights of the laboratory work being carried on follows.

With the increasing need for rapid control of metallurgical processes, perfection of techniques for direct spectrographic analysis has occupied the attention of the Section. Particular interest has been aroused in direct reading spectrographs constructed in Belgium under license of Macq. As a result of CNRM's activity, such a piece of equipment has been installed at one zinc plant permitting the rapid determination of nine elements in zinc; a second installation permits the direct analysis of impurities in lead and cadmium.

The metallographic and electronic microscopes at Liège have permitted the laboratory to undertake a number of special projects. One of these pertains to the principal aspects of bainite belonging to different classes of TTT curves. This has permitted an interpretation of the role of surface stresses and an understanding of the influence of structure on the formation of hydrogen flakes. The structure and aging characteristics of low carbon steels are also under study.

An intensive study of metal flow at elevated temperatures is being undertaken. A number of special steels have been investigated, but one of particular interest has been an alloy of 9 pct Cr, 1.8 pct Mo, and 2.2 pct Co for use in making high pressure boiler tubes.

At the request of the Centre d'Information du Cobalt, the Liège section of CNRM has undertaken

a vast program on cobalt alloys. Part of this work has concerned the Fe-Cr-C-Co equilibrium diagrams. Further, the laboratory has been studying the influence of cobalt on the structural, mechanical, and chemical properties of many types of carbon and alloy steels. Initial results of this work show that, in general, cobalt has little direct effect on the matrix of low alloy steels, but in stainless steels of more than 13 pct Cr, the effect of cobalt manifests itself by a diminution of the speed of austenitic transformation. The laboratory has observed in many cases the favorable influence on high-temperature properties of cobalt added in low-alloy and stainless steels. Flow, forgeability, and oxidation resistance seem particularly significant.

The Liège laboratory has installed special furnaces for the preparation of large single crystals. Two techniques have been used in their preparation: work hardening and fusion in a soft mold.

Finally, the X-ray diffraction laboratory has pursued the development of a technique for the simple and rapid control of the skin in the skin-pass cold-rolling technique for sheet steel. A fine focus X-ray diffraction instrument is used for the preparation of a scale of standard specimens which can be compared with specimens from the rolling mill. This technique is also used to evaluate the supplementary deformation in the skin-pass.

Research in metallurgical plants

The plant research work of the Liège section of CNRM has had as its principal object, improving the quality of basic bessemer steel, which constitutes some 80 pct of Belgian and Luxembourg production. Other matters investigated include: the correlation between the mechanical properties and the chemical analyses of cold-rolled strip, agglomeration of ore fines, reducibility of ore, improvement in blast-furnace technique, and the physical-chemical reactions of slag and metal.

In regard to basic converter techniques, the use of oxygen-steam blowing has been the subject of a great deal of work. This technique permits the production of steel with 0.0025 pct N_2, and it has been found possible to reduce phosphorus to 0.020 pct by using a double slagging operation. Today about 50 pct of the Belgian-Luxembourg steel production is made by this double-slagging oxygen-steam blowing process.

Blowing steel with an oxygen-steam mixture has lead to a valid quiry regarding the probable increase in the hydrogen content of the metal. This has been the subject of a special study at Liège which has shown that the hydrogen content of steels blown with oxygen-steam is higher than for those blown with oxygen-enriched air; the difference is 9.5 cu cm per 100 g compared with 3 to 4 for the latter. Experimental work has revealed that, when the bath is blown with air or oxygen-enriched air after the removal of the phosphorous slag, the hydrogen content of the metal drops to values identical with those of steel converted entirely with air or oxygen-enriched air.

The use of pulverized lime in an oxygen lance has also been the subject of industrial research by the Section, and a new plant-scale installation has been constructed to carry out this work on refining high-phosphorus pig irons.

In regard to the control of the converter operation, the Section has developed a photoelectric technique of flame observation, a direct spectral analysis method, and an immersion thermocouple for measuring bath temperatures.

Hainaut section

The Hainaut section of CNRM in Charleroi, Belgium, has developed its plant and laboratory experimental program toward the perfection of new techniques and processes, particularly the basic bessemer or thomas process, and continuous casting technique.

However, since its foundation, the Section has largely concentrated on laboratory research work. This has included work on the quantities of oxygen, hydrogen, and nitrogen in ferrous metals. A study has been made of the isolation of inclusions by iodine in an alcohol atmosphere, bromine in an ester atmosphere, and by electrolysis according to Klinger and Koch and Sobiesky.

Numerous problems have been studied by X-ray diffraction and fluorescence; these are applicable to the study of metals, inclusions and slags.

The mechanisms of the rupture of steel is being studied by means of high-speed photomicrography and by tests in the Robertson tensile machine. The results are compared with radio spectrographic observations.

The Hainaut section also has several furnaces which permit experimental work to be carried on with many types of steel. One is a vacuum or controlled-atmosphere furnace, which facilitates the study of diverse elements on the properties of metals.

Plant experimental work of the Hainaut section is concerned with two matters: a study of the control and standardization of the thomas process, and a study of the optimum operating conditions of the blast furnace. The former study includes blowability, temperature changes, and the calculation of the termination of the operation, including after-blowing.

Continuous casting has been the subject of extensive study by the Hainaut section. The program is directed into two main channels: killed electric or thomas steel in sizes from 90 mm sq to 125 mm sq, and rimming thomas steel in sizes of 175 mm sq to 200 mm sq. During 1957, a pilot plant for vertical continuous casting was designed and built at the works of the Aciéries et Minières de la Sambre.

This plant was designed or four independent lines: one for 90 mm sq billets is already operating, and a second for 200 mm sq rimming steel is under construction.

The 90 mm line has a thick-walled copper mold, suspended by an elastic method. As it emerges, the billet is cut into 4.5 m lengths by an automatic torch.

Horizontal continuous casting is also the object of some study by this section of CNRM. The problems of the tearing of the ingot so cast have been investigated extensively.

Conclusions

These are but the highlights of the work of these two sections of the Belgian National Research Center. To describe all of their activities would indeed be beyond the scope of this article and several others as well. But the examples cited will serve to show what is being done in the way of metallurgical research to keep the Belgian metals industries at a point of high technological development.

GERMANIUM,

ZINC'S IMPORTANT BYPRODUCT

A pioneer of germanium as well as Europe's oldest and largest producer of zinc is Vieille-Montagne. Germanium output is centered at the zinc-lead plant of Balen, Belgium, where it is a byproduct of electrolytic zinc.

Balen, Belgium

by Theophile Boving and Jean Andre

DISCOVERED in 1886 by the German chemist, Winkler, germanium was, until the last few years, merely a laboratory curiosity. However, its particular physical properties in electrical semiconductivity, revealed and used since World War II, are giving it an even more brilliant future in electronics.

Germanium is, in most cases, found in very small quantities associated with zinc, lead, and copper ores. It is essentially a byproduct of the zinc and copper industries and particularly of electrolytic zinc metallurgy. It was, thus, only natural for Europe's largest zinc producer, the Belgian firm, Vieille-Montagne, to become one of the pioneers in germanium.

Byproduct of lead-zinc complex

Germanium has been produced since 1949 in the largest electrolytic zinc plant of Vieille-Montagne at Balen, Belgium. Created in 1889, Balen is now an industrial complex covering 70 acres. It is an exceptional example of the integration of an electrolytic zinc plant, a lead plant, and a sulfuric acid plant, as well as facilities for recovering numerous byproducts.

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Zinc ores generally contain some lead, and lead ores contain some zinc; so, it was altogether logical to integrate as completely as possible the metallurgies of both of these two metals in order to permit the recovery of all of the lesser metals. This was progressively realized at Balen in the following manner:

1) Lead furnaces produce lead bullion and zinciferous slags which retain some lead and the greatest part of the zinc contained in the lead ore. These slags are fumed in a blast furnace (Philipon process hot-air blast), and the resulting oxide is one of the raw materials for the manufacture of electrolytic zinc.

2) Sulfuric leaching of both the raw zinc calcines and the blast-furnace oxides gives a residue containing the non-dissolved zinc and all of the lead. When the lead content of these residues is high, they are used as a raw material for the lead plant. Otherwise, they are treated in the blast furnace for zinc recovery.

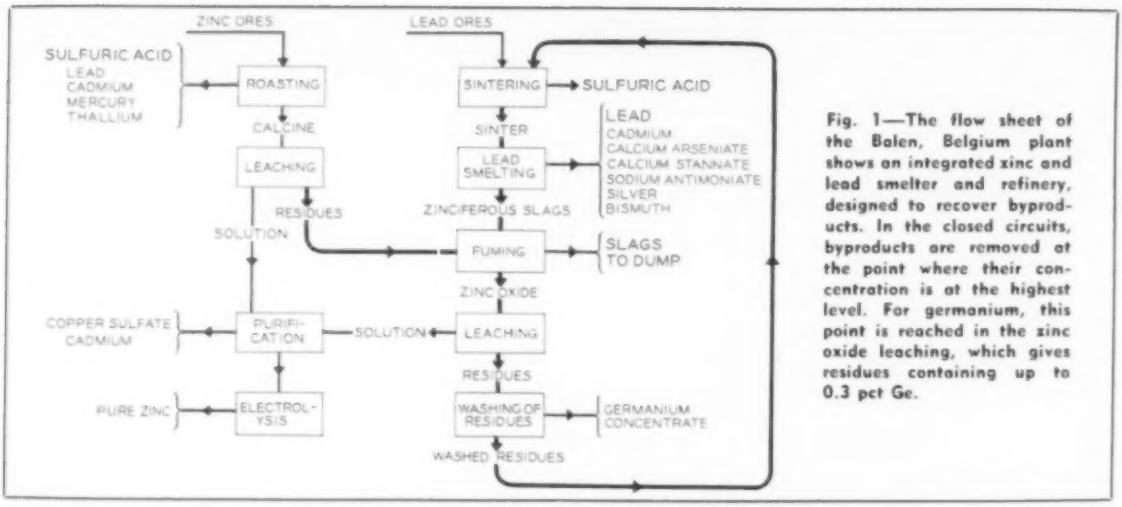

Fig. 1—The flow sheet of the Balen, Belgium plant shows an integrated zinc and lead smelter and refinery, designed to recover byproducts. In the closed circuits, byproducts are removed at the point where their concentration is at the highest level. For germanium, this point is reached in the zinc oxide leaching, which gives residues containing up to 0.3 pct Ge.

This metallurgical integration offers the best conditions for the rational recovery of all of the lesser metals contained in lead and zinc ores. Such byproduct metals are first concentrated in residues, dusts, and slimes either when roasting or else in the electrolytic circuit. Appropriate metallurgical treatment enables Balen to turn out silver, cadmium, bismuth, mercury, thallium, copper sulfate, sodium antimonate, calcium stannate, calcium arseniate, and germanium.

Concentrated in circuits

Germanium was first manufactured at Balen in 1949, but its presence in the solutions of the electrolytic zinc plant had been noticed long before when it was not a question of recovering the metal to meet the demands of the electronics industry. In fact the presence of minor quantities of germanium —less than 0.1 mg per liter—in the zinc solution causes a large decrease in current efficiency, and might render the electrolytic process uneconomic. The risk of this was increased by the integrated metallurgies at Balen, because all of the materials flow in closed circuit, as is shown in Fig. 1.

Germanium enters the cycle largely in the zinc calcines which run from 10 to 400 g of Ge per metric ton. Some is dissolved with the zinc but is precipitated before the solution is transferred to the electrolytic cells, while the remainder passes along with the residues.

There are duplicate leaching circuits in the plant: one for treating raw calcines, and the other for treating oxides from the blast furnace. Residues from the oxide leaching have a sufficiently high lead content to be treated in the lead furnace. This treatment results in a slag which retains the zinc and germanium.

Residues from the calcine leaching generally have too low a lead content to be treated in the lead furnace. Instead they are fumed in the blast furnace, together with the slags from the lead furnace, in order to recover zinc values. Zinc recovery is about 70 pct.

The reducing atmosphere in this blast furnace is such that almost all of the germanium charged is volatilized at the same time as the zinc, so that the germanium is found once again in the zinc oxide which is sent to the leaching circuit.

Thus, it may be seen that, owing to this treatment in a closed cycle, germanium was building up continually in the circuit. It increased to such an extent that it was not unusual to treat at the electrolytic plant zinc oxide containing more than 0.1 pct Ge, i.e. 20 times more than the germanium content generally considered as a maximum limit in the ores.

The electrolysis would soon have become unworkable, had not special measures been taken to rid the electrolyte of germanium. So it was that the separation of germanium from the solution was one of the major problems that had to be solved in the electrolytic process at Balen. When it became evident that this unwanted element was of great value, a recovery and purification process was finally developed.

First, a germanium concentrate

Germanium is taken out of the given closed circuit at the very point where its concentration is at its highest level. This point is reached in the zinc oxide leaching, which gives residues containing up to 0.3 pct Ge. Advantage is taken of the solubility of germanium in water at appropriate pH and temperature, and the washing of these residues enables the greatest part of the germanium to be dissolved. After filtration, germanium is selectively precipitated at appropriate pH and temperature. The resulting cake contains 2 to 3 pct Ge.

From concentrate to metal

In principle the steps in the manufacture of germanium metal at the Balen works in Belgium include:

1) Digestion of germanium concentrate in hydrochloric acid to obtain $GeCl_4$;
2) Purification of the tetrachloride by distillation;
3) Hydrolysis of the pure tetrachloride to obtain GeO_2;
4) Reduction of the dioxide to germanium metal;
5) Physical refining of the metal; and
6) Control of the quality of the metal.

1) Germanium tetrachloride

The germaniferous concentrate is heated in an enclosed vessel in the presence of hydrochloric acid. The resulting germanium tetrachloride has a boiling point of 83°C and is thus readily distilled and condensed in flasks filled with pure hydrochloric

acid in which it is miscible when hot. Quartz balloon flasks of large capacity are used for digesting the germanium concentrate.

The germanium tetrachloride, thus produced, is quite impure, but it is passed through a double distillation in a medium saturated with chlorine in order to remove as much arsenic as possible. After this treatment the tetrachloride still contains up to 0.01 g of As per l, along with other impurities; this impure product is transferred to another room for purification.

2) Purification of the tetrachloride

Purification is carried out by distillation under a flow of chlorine. Round flasks, charged with $GeCl_4$, are connected in series of seven, are surmounted with Widmer columns followed by a refrigerator. Germanium tetrachloride is introduced into the first round flask and slowly heated; it evaporates and is condensed in the following round flask, which in turn is heated as soon as the first flask has emptied its tetrachloride. The tetrachloride distilled in the last flask is condensed in a storage flask, located in a separate room.

Such a purification system is quite standard. However, the following feature is considered distinctive: before introduction of the germanium tetrachloride, each flask contains some high-purity hydrochloric acid. Germanium tetrachloride and hydrochloric acid are immiscible, so that the two liquids separate into distinct phases. In this way the condensed germanium tetrachloride must pass through several beds of pure acid which tend to dissolve the residual impurities. So, there are, in reality, two purification processes in operation: distillation and treatment in pure acid.

3) Hydrolysis

A plastic tank of some 200 l capacity with a mechanical agitator is used for hydrolysis. The tank is filled with water of low ion content and consequent high resistivity—more than 5 million ohm-cm. The agitator is started, and pure germanium tetrachloride passes into the tank, drop by drop, where it hydrolyzes immediately. Upon completion of this operation, the tank contains germanium hydroxide in suspension, and this is filtered through orlon canvas. Only plastic material is used for this equipment so as to avoid introduction of foreign metallic elements into the germanium compounds.

The white filter cake of germanium hydroxide is placed with care in quartz bell jars, which are put into an electrically heated furnace to dry and calcine the hydroxide into a powder of germanium dioxide. This material still contains some agglomerates, which are later removed by passing through a vibrating nylon sieve.

This product is packed in 1-kg containers. Germanium dioxide is a commercial product, since some customers prefer to carry out the reduction of the oxide and subsequent operations themselves. Nevertheless, in order to satisfy all customers, Vieille-Montagne has equipped a division for reduction and refining to an electronic metal.

4) Reduction of the oxide

Germanium dioxide is reduced with hydrogen gas in a two-stage operation which prevents the formation of germanium oxide—GeO. These are accomplished in electrically heated tubular furnaces. In the first stage, reduction is carried out at 650°C, under a flow of dry hydrogen, giving a grey-black powder which is unmelted metallic germanium. It is then possible to raise the temperature gradually to 1000°C, still under a flow of pure dry hydrogen. After cooling, a bar of germanium is withdrawn. It has a metallic appearance and already an impressive high purity.

5) Purification of the metal

Electronic devices require a metal which is still purer than that already achieved. Fortunately, a process called *zone melting* has been perfected which enables the required results to be achieved. This technique, which depends upon the greater solubility of impurities in a melted substance than in a solid substance, is used on bars of reduced germanium metal. A liquid zone is made to travel from one end of the bar to the other, and owing to the greater solubility of impurities in the liquid zone, the latter will carry these impurities to one end of the bar.

In usual practice the bar to be purified is placed in a boat of high-purity graphite, and the latter in a quartz tube. An atmosphere of pure and dry argon surrounds the ingot in the tube during the zone refining. The boat is moved slowly—4 mm per min—in a field of six coils supplied with radio frequency current, which enables a narrow melted zone to be achieved.

6) Control of quality

It would be impossible to check the purity of both oxide and metal by standard chemical or spectrographic tests. But control of impurities is easily achieved because of the great influence that impurities have on the resistivity of the metal. This measurement is standard, and does not present any difficulty. The quality of the oxide is checked by reducing it to metal and checking the resistivity of the resulting metal.

For other tests, metal of a single crystalline structure is required for accuracy of testing, and the preparation of single crystals of germanium is now well perfected.

High-purity silicon, a competitive material

Research is being conducted on other semiconductor materials. At present the nearest competitor to germanium is silicon. There are three big US producers of this material: duPont, Eagle-Picher, and Sylvania. Several domestic and foreign firms are also working on this, and it can be expected that they will enter the market in the not too distant future—Vieille Montagne is one.

The future for silicon appears every bit as bright as that for germanium (and perhaps even brighter) since the supply of raw materials is not a problem. Whereas germanium is a byproduct, high-purity silicon can be considered as a primary product. The uses for silicon at present include transistors, diodes, power rectifiers, solar cells, and the atomic battery.

Conclusions

The advances in the uses and in the processing of germanium during the past decade have been almost phenomenal, and it is certain that new developments will continue; therefore, a continuation of the growth of germanium for the next decade can be predicted. Even if its future growth is only half as spectacular as its past, germanium will have more than lived up to its expectations.

HIGH-PURITY COBALT ... ITS PROPERTIES

A research-in-progress report on the basic properties of high-purity cobalt. Control of purity and process were found to be extremely important for accurate results.

by F. R. Morral

Table I. Chemical Analysis of Cobalt[a]

	Impurity Content, Pct by Wt				
	Rondelles: Analysis by		Zone Refined, by Battelle[c]	Powder: Analysis by Supplier[d]	Electrolytic
	Supplier[b]	Battelle[c]			
O_2		0.0092	0.0031		0.0119
H_2		0.0001	0.00003		0.0035
N_2			0.002		
Ni	0.0	0.001	0.001	0.1	0.20
Fe	0.007	0.003	0.003	0.01-0.04	0.01
Mn	0.003	0.003	0.003		
Cu	0.0	0.002	0.002		0.002
Cr		0.001	0.001		0.01
Si	0.005	0.005	0.003	0.01	0.01
Ca		0.01	0.002		
Mg		0.002	0.001		
S		0.0		0.01 max	0.01
C	0.003		0.001	0.025 max	
Pb	0.0			0.02	
MgO	0.002				
CaO	0.01			0.02-0.05	
Al_2O_3	0.0				
Loss by H_2	0.023			0.04-0.08	
Co (balance)	99.947	99.963	99.98	99.7	99.75

[a] All are spectrochemical analyses except as follows: carbon by ignition; nitrogen by Kjehldahl; oxygen and hydrogen by vacuum fusion. [b]Spectrochemical analyses are accurate to ± factor of 3 (±3X, or −2.3X+), and vacuum fusion for oxygen and hydrogen to ±0.7 ppm and ±0.009 ppm, respectively.
[b] Analysis by the supplier, Union Minière du Haut-Katanga.
[c] Spectrochemical analysis at Battelle.
[d] Specification by the supplier, Charles Hardy and Company. The cobalt balance is only an indication, of course, since the same elements were not determined in each lot, and a direct comparison of cobalt content cannot be made.

THE Centre d' Information du Cobalt, Brussels, Belgium, has, over the past several years, sponsored a series of investigations, the purpose of which was to widen the knowledge of the basic properties of cobalt. Many of the contradictions, which are found in the early data on this element,[1] are attributable to the use of impure materials. However, 99.95 pct Co has recently been made, new experimental techniques have been developed, and old techniques have been improved.

Zone-refined cobalt

During 1957, the Battelle Memorial Institute zone-refined some cobalt for the Cobalt Information Center, using induction heating in a three-turn pancake-type vertical coil. This improved the purity of the cobalt from 99.95 to 99.98 pct, Table I. A previous attempt to zone refine cobalt had been made by another laboratory, but they experienced contamination from the crucible.[2]

F. R. MORRAL is with the Cobalt Information Center, Battelle Memorial Institute, Columbus, Ohio. Part of this paper was presented at the 1958 AIME Annual Meeting in New York and part at the 1958 AIME Pacific Northwest Conference in Spokane, Wash.

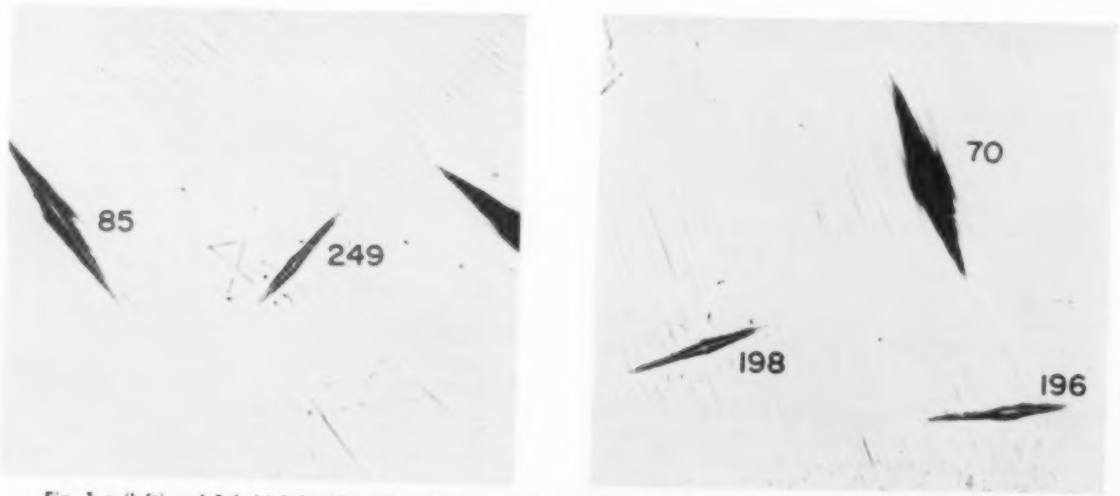

Fig. 1 a (left) and 1 b (right)—Metallographic appearance of zone-melted cobalt, showing the effects of grain orientation on hardness. Magnification, 250X, reduced one half.

Fig. 2—Zone-refined cobalt heated to 420° to 440°C in vacuum. Note thermal etching. Magnification 100X.

The lattice constants were determined from the zone-refined cobalt and are compared with those reported by Taylor and Floyd[5] in Table II. The measured density agrees well with that calculated from the X-ray diffraction data.

Room temperature hardness tests on the zone-refined cobalt showed large differences in hardness reading, 81 to 249 BHN, depending on the orientation of the hardness impressions within a crystal. The extremely clean and narrow grain boundaries shown in Fig. 1 reflect the high purity of the metal. A few twins have formed either on cooling or from mechanical deformation. There is a ragged grain boundary at the left of Fig. Ia which appears to be in the process of migration.

The type of deformation process operating seems to depend on the orientation of the indentation within a grain. Note the deformation trailing away from the indentation in Fig. Ib and Ic. In one instance, not reproduced, there was extensive deformation even in the next grain.

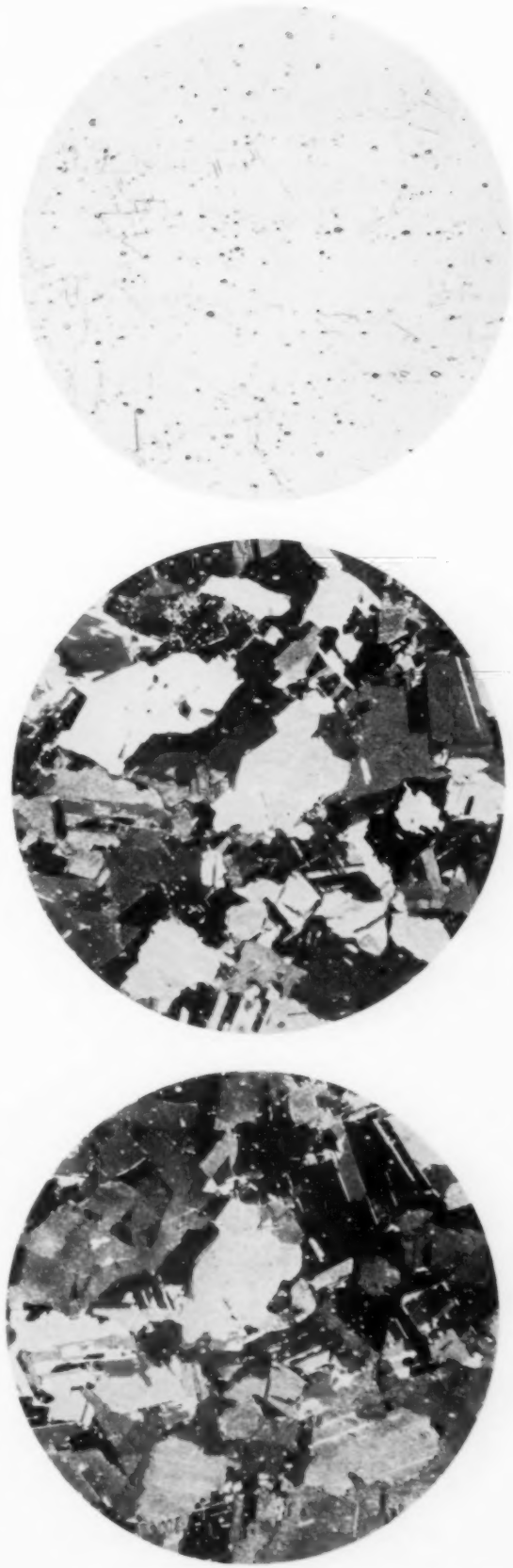

Fig. 3 (right)—Hot-worked cobalt microstructure, 250X. Top (a), under non polarized light. Middle (b) and bottom (c) under two orientations of polarized light at 45°. Face-centered grains are dark under polarized light, regardless of orientation. Those grains that appear black in (b) and (c) must, therefore, be fcc grains.

Table II. X-Ray and Density Data of Hexagonal Close-Packed Cobalt

Reference	Preparation History	Lattice Constants, Angstroms a_0	c_0	c/a	Calculated Density[a], G per Cu Cm	Measured Density, G per Cu Cm	Remarks[d]
Taylor and Floyd[1]	Quenched from 400°C	2.5074	4.0699	1.623	8.832	—	Considerable fcc β-Co present; a_0 = 3.561
Present work	Zone refined[e]	2.5059	4.0695	1.624	8.844	8.845[b]	Some fcc β-Co present
Present work	Powder metallurgy	—	—	—	—	8.90[b]	No fcc β-Co detected
						8.71[c]	

[a] Using the following constants: At wt = 58.94; Avogadro's Number = 6.0228×10^{23}.
[b] By water immersion.
[c] By physical measurement.
[d] Presence of β-cobalt determined by X-ray diffraction using Fe-K radiation.
[e] Material annealed.

The high hardness seems to be associated with twinning (1120), and low hardness with extensive basal slip on the (0001) planes. Basal slip seems to experience little work hardening, which is suggestive of easy faulting.[4] If faulting on the basal plane is easy, the total amount of deformation (indentation) obtained in the most favorable case may be less than if no faulting existed and may also result in the introduction of other-than-basal slip. Although cobalt should be susceptible to such faulting, there seems to be no evidence of complex slip, at least due to hardness indentation.[4]

A thin sample of this zone-refined cobalt (Fig. 2) was heated in a vacuum of 2×10^{-5} mm to 420 to 440°C and held for two days. The original structure, shown by thermal etching (reading 400°C), has been designated on the micrograph. The balance of the slip planes appeared between 20 and 50 min after the power was turned off and while the sample probably passed through the allotropic transformation temperature (changing in part from fcc to close-packed hexagonal).

Table III. High-Temperature Hardness of Cobalt

Temperature, °C	Vickers Hardness Number: Zone-Refined[a]	Electrolytic: Present Work[b]	Electrolytic: After Chubb[5]	Electrolytic: After Brenner[6]	Powder Metallurgy[b]
R.T.	253[a]	336	239	370[a]	225
200		245	232		
300	143	209	212		141
350		196	167		
400		159	135	255	
425	109	140	136		119
450	98	121	121		115
475		119	109		
500		83	102		
550		63	78		
600	43	54	63	78	62
750	26				39
800				38	
900	17				22
R.T.	192	284		290	177

[a] Values estimated from figure in original paper.
[b] Held one hour at 500°C after hot rolling.
[c] For analysis, see Table I.

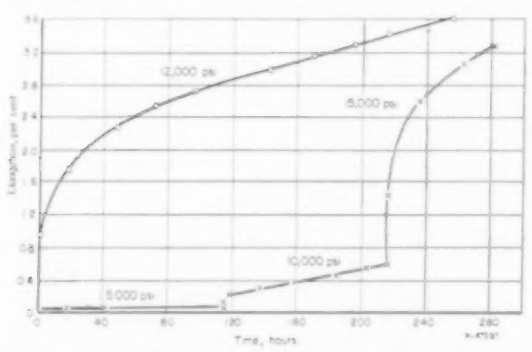

Fig. 4—Creep curves for powder-metallurgy cobalt at 500°C according to Adkins, Sims, and Jaffee.[7]

The microstructure of cobalt fabricated to 0.060 in. sheet from sintered bar is shown in Fig. 3. These micrographs show how polarized light may be used to differentiate the fcc high-temperature from the room-temperature hexagonal phase.

Changes in hot hardness with temperature were measured on cobalt of different origins: zone-refined, sheet (Fig. 3), and electrolytic cobalt (99.75 pct Co flake used in alloy making). Table III compares the data obtained with that reported in the literature. After raising to temperature, the hardness of the material was then checked after cooling to ambient temperatures. A parallelism in behavior among the various types of cobalt is evident, both on heating to 900°C and after cooling. The differences in hardness at room temperature are, no doubt, associated with the impurities, gas content, and relative amounts of α (close-packed-hexagonal) and β-Co (fcc) phase present.

Data on creep were recently obtained by Adkins, Sims, and Jaffee[7] and are summarized in Fig. 4. Allen and Carrington[8] reported the creep stress of cobalt for 10 pct deformation in 24 hr at 1000°C as 1388 psi. C. R. Austin and J. R. Gier[9] determined the creep rate of cobalt using a modified Rohn test. No comparison is made because of the different measuring techniques and temperatures used.

These limited data suggest the importance of control of purity and processing when studying metals. A metal, such as cobalt, which has a rather low temperature allotropic transformation (420°C), presents additional problems. Because of this, the investigator must use caution and, before embarking on a theory, he must know the relative amounts of the two phases present.

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In Belgium

ZINC RETORTS OPERATIONS MECHANIZED

by Albert Ghysens

ONE of the major problems associated with the operation of horizontal zinc retorts has been the very hard work involved in charging and discharging. For many years attempts have been made to design machines to mechanize these operations, but the results have not been wholly satisfactory.

Europe's largest zinc producer, Vieille Montagne, thus, set about designing suitable charging and cleaning-out machines.

Charging machine

The charging machine, shown in Fig. 1, consists of a frame fixed on supporting wheels, travelling in a direction parallel to the furnace face, and supporting a thrower-casing topped by a hopper containing sufficient charge for 24 retorts. Inside of the machine a short rubber belt rotates at high speed between two rollers, as is shown in Fig. 2. The ore-coal mixture from the hopper falls tangentially onto the vertical part of the belt. It is thrown by means of a paddle-wheel onto the lower concave part of the belt and is jetted into the retorts through a throw-pipe at a speed of 20 m per sec.

Today, many Belgian and foreign zinc smelters are fitted with these machines for charging horizontal retorts. Advantages derived from this mechanical charging method are: 1) an increase of production of 6 to 7 pct resulting from charging an increased weight of material into the retorts, 2) regularity of the quantity charged in each retort which gives a better resistance of the retorts, 3) total suppression of arduous hand charging, and 4) labor saving amounting to 33 pct.

Cleaning-Out machine

A cleaning-out machine for the horizontal zinc retorts was also developed in one of the smelters of Vieille Montagne several years ago. Its originality lies in the fact that it carries out exactly the motion of the cleanout ladle previously used by the worker.

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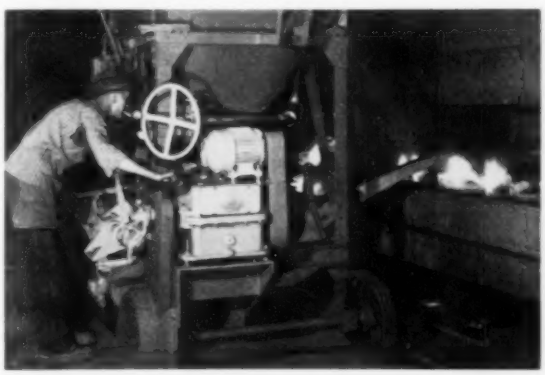
The machine comprises a support chassis which moves in front of the furnace on the same rails used by the charging machine. On this chassis is mounted a horizontal tool supporting frame, which may be raised, lowered, or inclined according to the height and slope of the row of retorts. The frame has four ladles or tools of the same shape as those previously used with hand cleaning, except that they are somewhat longer. As a rule five to six successive passes are sufficient to clean out completely four retorts in about 1 min. According to the sticky state of the residues, the ladles may be cooled with water or not. Operating and maintenance costs are small; the working tool itself is a very simple shape made of carbon steel, hence a low-cost replacement.

Advantages derived from the cleaning-out machine are: 1) decrease in working time at the furnaces, 2) suppression of the hard work of hand cleaning-out, and 3) better cleaning-out.

Both machines working together have permitted a 50 pct saving in labor and a greater ease in hiring and retaining workers. This important improvement, that has been brought to the old horizontal retort process, is the result of close collaboration between the research and manufacturing departments of Vieille Montagne in Belgium.



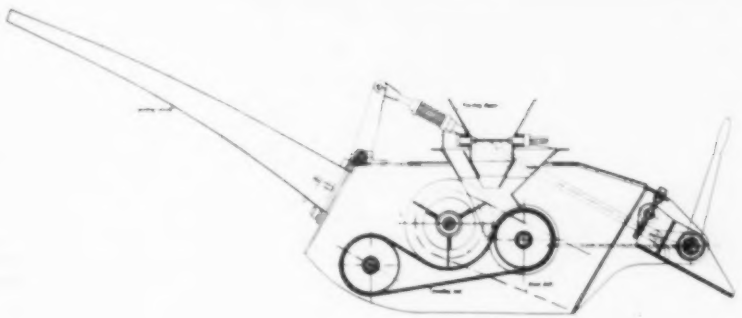


Fig. 1 (above) and Fig. 2 (right) —Simplicity of design of these charging machines has relieved the arduous manual labor traditionally associated with the operation of horizontal zinc retorts. In addition, higher production and longer retort life have been achieved.

Opening Session in Luxembourg. Left to right: Mr. Wheeler, President of the Iron and Steel Institute; M. Perot, President of the Belgian Metallurgical Research Institute; M. van der Rest, President of the Belgian Blast Furnace and Steel Federation; M. Coheur, President of the Executive Committee of the Conference; M. Malcor, President of the French Ferrous Research Institute; and Mr. Headlam-Morley, Secretary of the Iron and Steel Institute.

WORLD'S FERROUS METALLURGISTS MEET IN BELGIUM AND LUXEMBOURG

by F. Weston Starratt

The Journées Internationales de Sidérurgie, a 10-day gathering of 1250 metallurgists and steel specialists, had as its theme, "New Iron- and Steel-making Processes."

Liège . . . 1400-year-old metalworking city on the Meuse river in eastern Belgium . . . was the host city to the opening of the Journées Internationales de Sidérurgie . . . the International Steelmaking Congress. The gathering brought together 1250 metallurgists and steel specialists from 32 countries and included many of the world's key ferrous metallurgists.

The meetings, organized by the Centre National de Recherches Métallurgiques—(the National Metallurgical Research Center), le Groupement des Industries Sidérurgiques Luxembourgeoises (The Luxembourg Steel Federation), and the Groupement des Hauts-Fourneaux et Aciéries Belges (the Belgian Blast Furnace and Steel Federation), was held on the occasion of the semi-annual foreign visit of the Iron and Steel Institute of the United Kingdom.

This 10-day round of technical meetings and plant visits, commencing in Liège, continued in two major steelmaking centers—Luxembourg and Charleroi—and terminated at the International Exposition in Brussels.

New iron and steel making processes

The theme of the Congress was explained by one of the organizers of the meetings, Pierre Coheur of CNRM, "During the last ten years, ferrous metallurgists of all countries have been particularly active. This activity has manifested itself, not only by the erection of new plants, the construction of new and more powerful means of production, more precise control of operations, but also, and, possibly above all, by the development of new production techniques."

"Our metallurgists have estimated that the moment has come to present the results . . . of the new steelmaking processes which are industrially practicable. They have proposed the organization the Journées Internationales de Sidérurgie toward this end. In the course of the meetings three major problems were studied:

1) **Ironmaking**, including direct reduction, methods of improving blast furnace productivity, and the low shaft furnace;

2) **New Steelmaking Processes**, including such new techniques for converting pig iron as Kaldo, Rotor, LD, oxygen-steam, and two oxygen-lime-powder methods, means of increasing open-hearth productivity, and larger capacity electric-arc furnaces;

3) **Continuous Casting of Steel.**"

Converting pig iron

With Belgian and Luxembourg steel production based largely on the basic bessemer technique, emphasis was given to the many new techniques for converting pig iron. Plant visits in the three steelmaking centers gave convention delegates the opportunity to inspect closely the oxygen-steam blowing technique, which is widely used throughout Belgium and Luxembourg.

One of the most interesting plant visits was at Charleroi, S.A. des Aciéries et Minières de la Sambre, where they practice oxygen-steam and oxygen-carbon-dioxide blowing. The technique is described on page 669 of this issue.

The la Sambre firm had just put into operation what is probably the first commercial installation for bottom blowing with powdered lime. They had completed an installation for pulverizing lime to 99 pct — 0.5 mm. Automatic handling equipment permits the lime to be used in oxygen-steam bottom-blowing practice on any of the plant's four 17-ton converters. The installation can blow up to 800 kg of powdered lime per min, with about 350 kg being blown per heat to cover most of the fluxing requirements.

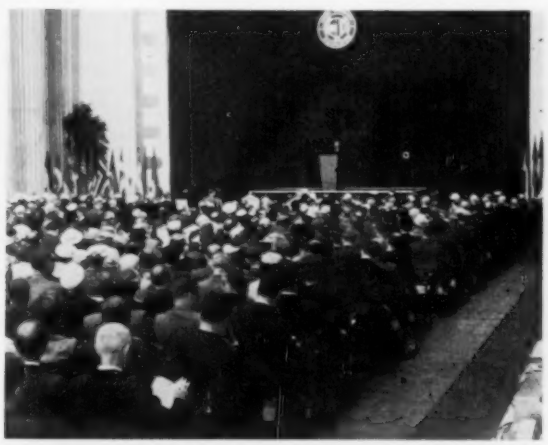
Those who had developed each of the major steelmaking processes presented papers at the technical sessions. Some of these papers already have been published in the JOURNAL OF METALS, and we shall be publishing some of the remainder during the next few months. On p. 673 of this issue is found the paper, *LD Produces Alloy Steels in Austria* by O. Cuscoleca and K. Rösner, describing how the LD technique is now being used for the production of high-carbon steels. H. Trenkler of VOEST in Austria also described the experimental working of intermediate phosphorus heats by the LD process. Results have been corroborated by operations at Pompey in France.

K. C. McCutcheon, Consultant for Armco Steel Corp., summarized this part of the conference. "It is clear that much progress had been made. At these meetings I was convinced that bottom and top blowing process are all flexible as to analysis control. This had previously been doubted by many. But I will say, that it was not clear to many of us what the actual effect was on the economics of the process."

The OCP process

A new converting technique for high phosphorus pig irons has been developed in Belgium after 10 years of research by the Belgian Metallurgical Research Center. It was the subject of an important paper by Paul Metz chief Engineer of ARBED's Dudelange plant. Initial work showed that the simultaneous injection of oxygen and lime powder made

Their Royal Highnesses, the Grand Duchess and the Prince of Luxembourg, conducted by M. Gabriel Chretien, Vice-President of the Luxembourg Steel Federation, and M. Fourneau, Director General of the Société Minière & Métallurgique de Rodange, to the opening of the Luxembourg sessions.



June 23rd, the opening session of the Journées Internationales de Sidérurgie in Luxembourg at the Noveau Palais des Expositions.

it possible to eliminate the phosphorus during the decarburization process. In the practice, which was developed, the converter is charged with hot metal, most of the scrap, about 1/3 of the total lime, some bauxite, and a limited quantity of ore. The oxygen lance is first placed in a high position and oxygen blown in at a rapid rate; later the lance is lowered, and pulverized lime is blown with the oxygen. A single or double intermediate slagging is practiced. Total blowing time varies between 16 and 20 min.

Results: One of the aims of the research was to develop a process which would permit a high scrap rate and a corresponding reduction in pig-iron consumption. This has been achieved with scrap rate of 215 kg per metric ton of steel, and a pig-iron rate of 878 kg. Other results may be summarized as follows:

1) high metal yield—90 pct
2) low oxygen consumption—1900 to 2050 cu ft per metric ton of pig iron,
3) low lime consumption—186 lb per metric ton of steel,
4) high speed of refining—35 to 45 sec per metric ton of steel,
5) ease of dephosporization even with high final C content, and
6) production of steels of less than 0.02 pct S and P and 0.004 pct N_2.

It follows that this is an economical process suitable for the production of high quality steels.

Open hearth practice

A major technical session was devoted to the open hearth practice, with an excellent review of British developments, *The Driving Rate of Open-Hearth Furnaces*, presented by R. W. Evans et al, as well as a review of US practice by Lightner and McBride.

While there were at least a dozen Soviet engineers in attendance at the meetings, none of them had registered in advance; so, they were not recorded in the official *Who's Who* of the conference. None of them presented formal papers, although they participated in each discussion, making statements as to Soviet achievements in whatever aspect of steelmaking was being discussed.

The delegation included A. M. Samarin, whose article *Vacuum Treatment of Steel in the Soviet Union* appeared in the March issue of JOURNAL OF METALS, pp. 190 to 192. In the discussion, he stated briefly that much could be accomplished with vacuum treating converter steels to reduce gas content. Such techniques, he claimed, are cheaper than the LD process with its relatively high cost of oxygen. He also advocated vacuum treatment for desulfurization, and went on to say that vacuum treated steels had superior structure and less segregation when used with continuous casting techniques.

A Soviet authority on the operational side of open-hearths is A. Morozov who discussed Soviet open-hearth practice. We briefly mention some of his remarks from hurriedly copied notes, although at a later date, JOURNAL OF METALS hopes to print his full text. He told how a great number of open-hearths in USSR are now being equipped to use oxygen in the fuel burners to increase temperatures, particularly during the melt-down period. Air for the burners is enriched with oxygen up to 30 pct. The practice results in more efficient combustion, which decreases the fuel rate by 15 pct, while capacity was increased about 17 pct. In 1952 water-cooled oxygen lances were tried out in the open-hearths of the USSR on the slag-metal interface. The extruded copper lance was used on up to 110 heats.

A session was devoted to the electric-arc furnace, with a paper on the new 150-ton furnace at the Fabrique de Fer de Charleroi in Belgium and a review of US practice by Ogan and Carney. Direct reduction techniques were the subject of two papers: one by Cavanagh of Canada and the other by Scortecci of Italy. We hope to see something further about these in future issues of the JOURNAL OF METALS.

Blast furnace

The blast furnace practice session featured a review of British operations by Colclough and a review of the Weirton experiments by Strassburger. Linder of Sweden gave a paper describing a program-controlled test of blast furnace burden materials which should be better than previously used reduction tests.

With many of the blast furnaces of Europe forced to operate on burdens of relatively low iron content, it is natural that some emphasis was given to the beneficiation of blast furnace burden. J. Astier of the French Steel Research Institute, IRSID, presented a paper reviewing the European practice of using a high-sinter burden. He described the successful experiments carried out in Lorraine when using 44, 51, and even 65 pct sinter in the charge. From October to December 1957, tests were made by IRSID on a blast furnace at the Dilling plant in the Saar. This was a rather small furnace of only 485 cu m volume, a height of about 20 m, and a hearth diam of 5 m. Operations confirmed the favorable results of similar tests carried out at the Appleby-Frodingham plant in the UK. Producing up to 530 metric tons of pig iron per day, the corresponding coke consumption was only 363 tons.

Continuous casting

The last two sessions in Charleroi were on continuous casting. They were well attended and gave evidence of the great interest that there is in this subject. Delegates also had a chance to inspect the experimental, continuous-casting plant of the Hainaut section of CNRM. The Soviets showed a film of their continuous casting operation at Novo Tula.

Conclusions

Taking part in the technical sessions, which included 34 major papers and many hours of discussions, were over 1200 leading ferrous metallurgists from all over Europe, both east and west, as well as many from overseas countries as far away as Japan. Also of high interest was the active participation in the meetings of those who had developed most of the new steelmaking techniques. Much was thus gained from the technical meetings, but perhaps equally important, were the personal contacts, which were possible in the luncheons, receptions, and dinners.

And finally a hand of thanks is certainly in order for the 19 plants and laboratories in Belgium and Luxembourg which so graciously opened their doors to members of this steel conference.

More will be heard about the Journées Internationales de Sidérurgie in future issues of the JOURNAL OF METALS.

CONVERTER PRACTICE AT LA SAMBRE

Both oxygen-steam and oxygen-carbon-dioxide blowing practice are used on an industrial scale to produce low-nitrogen, basic-bessemer steel at this Belgian mill.

Translated from an Article by M. Demarez

APPLICATION of oxygen to the basic-bessemer process has been foremost in the development efforts of the Aciéries et Minières de la Sambre (AMS). Since April, 1953, oxygen-enriched blast—28 to 34 pct O_2—has been used in plant operations, resulting in improved steel quality, a 15 pct increase in capacity, and a more flexible operation.

AMS, furthering these efforts to produce low-nitrogen thomas steels, has tested on an industrial scale two bottom-blowing converter practices: oxygen-steam and oxygen-carbon-dioxide. Since 1947, semi-commercial operations have shown that the use of oxygen and carbon dioxide in equal volume portions results in very low nitrogen content without impairing the removal of other impurities.

The AMS converter shop contains four 16.8-metric-ton units with cylindrical lining. Two are equipped for oxygen-steam or oxygen-carbon-dioxide blowing.

Two phase blowing

It has been well established that, whether converting is practiced with regular or enriched air, the nitrogen content of the metal reaches a minimum—about 0.0040 pct—at semi-decarburization, and then increases as a result of increasing temperature, lower carbon monoxide content, and concomitant increasing partial pressure of nitrogen, Fig. 1.

From an economic standpoint, it is therefore advisable to use the more expensive gases of low nitrogen content only after decarburization is half complete. Such a two-phase operation, using oxygen and carbon dioxide or oxygen-steam in the second phase, has been shown to produce steels of equally as low nitrogen content as those produced in a one phase blow with the same gases, Fig. 2.

To determine the opportune moment to commence the second phase of blowing, the converter operator uses an integrating instrument, which shows the total oxygen blown. The quantity of pig iron in the charge and its analysis permit advance calculation of the time when the special gases should be used. Changing to the second phase is accomplished in about 15 sec without interrupting the blowing.

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This paper was originally presented at the Journées Internationales de Sidérurgie, Liège, Belgium, June, 1958.

Precautions with oxygen-steam

Appropriate measures must be taken to protect the converter bottom if steam is used. The deleterious effect of steam on dolomite is reduced by superheating the mixture of oxygen and steam. But this alone is inadequate, and pipes used to distribute the fluids must be heated sufficiently to prevent condensation.

To establish proper conditions, the preceding heat is blown with pre-heated oxygen-enriched air. Pipe temperaure must also be adjusted in the course of the first phase when hot enriched air is blown at 300°C and at 350°C at the beginning and end, respectively. The second phase with oxygen-steam is carried out at approximately 350°C. Such precautions assure the total absence of condensation.

Gas mixtures and end point

To improve the thermal balance with either oxygen-steam or oxygen-carbon-dioxide blowing, to consume more scrap, and to reduce the duration of the process without affecting converter bottoms, the enrichment of the first phase of the blow to 32 to 35 pct O_2 is desirable.

For the second phase, the best gas mixture is about 50 volume pct O_2 with either steam or carbon dioxide. These proportions are determined in advance and maintained in the course of the blow by automatic instrumentation.

Oxidation occurs rapidly in the second phase, but the volume of the blast is held constant. Actually the effective concentration of oxygen is considerably greater than the free oxygen injected; with oxygen and steam, assuming steam dissociation at 70 pct, effective oxygen concentration is 67.5 pct, and with oxygen and carbon dioxide, assuming dissociation of the latter at 80 pct, effective oxygen concentration reached 70 pct.

During the final dephosphorization period, the two methods of blowing differ in their flame characteristics. When using oxygen and carbon dioxide, the flame is charged with reddish smoke, while no colored smoke is generated with oxygen and steam.

Although the end of the blowing operation can be determined from total oxygen input, it has been found more satisfactory to determine the time for tilting the vessel from the brilliance of the flame, Fig. 3. Contrary to air blowing, where it appears necessary to measure the ratio of flame brilliances in red and violet, a single photoelectric cell, receiving the total light rays, gives satisfactory results with oxygen-steam or oxygen-carbon-dioxide blowing.

On the basis of the results obtained from the first or second of a series of heats, the operator can tilt the converter and complete the blow with only one correction afterblowing for slag basicity and/or bath temperature, or two afterblows, interrupted with deslagging, if low phosphorus steel is required.

Table II. Typical Operating Data for Oxygen-Steam and Oxygen-Carbon-Dioxide Blowing
(two successive heats on same converter)

	O_2-Steam	O_2-CO_2
Pig Iron Charged, metric tons	18	17.2
Scrap Charged, metric tons	—	0.8
Lime Charged, kg per metric ton pig iron	135	143
Blowing Time	8 min 2 sec	8 min 29 sec
Final Temp, °C	1610	1612
Steel, Nitrogen Content, pct	0.0028	0.0026
Pig Iron Analysis:		
C, pct	3.45	3.50
Mn, pct	0.52	0.51
Si, pct	0.24	0.24
P, pct	2.10	2.14
S, pct	0.030	0.026

Plant description

Oxygen Plant: This plant consists of two Linde columns, each producing 630 cu m per hr of 98.5 pct O_2. Two 1000-cu-m storage tanks, one of which may be used for carbon dioxide, assure adequate supplies.

Steam Superheater: This heater, which can also be used for the enriched air, is supplied with steam at a pressure of 8 to 10 kg per sq cm and a temperature of 180° to 240°C. It consists of a burner, supplied with coke-oven gas and oxygen, and a reheating chamber where steam and oxygen are admitted.

Table I. Composition and Presumed Composition of Gases Blown into the Bath

		$O_2 + CO_2$ Process					
		Consumption, Normal Cu M per Metric Ton Pig Iron	Composition After Dissociation, Normal Cu M per Metric Ton of Pig Iron				
			O_2	N_2	A		Total
1st phase	air	78.0	16.2	61.8	—		
	O_2	12.6	12.4	0.1	0.1		
		90.6	28.6	61.9	0.1		90.6
2nd phase			O_2	CO	CO_2	N_2	A	Total
	O_2	28.1	27.7	—	—	0.2	0.2	
	CO_2	28.4	11.4	22.6	5.7	—	—	
		56.5	39.1	22.6	5.7	0.2	0.2	67.8

		O_2 + Steam Process							
		Consumption, Normal Cu M per Metric Ton Pig Iron	Composition After Dissociation, Normal Cu M per Metric Ton of Pig Iron						
			O_2	N_2	CO	CO_2	H_2	H_2O	A	Total
1st phase	air	44.00	9.2	34.8	—	—	—	—	—	
	gas[1]	3.62	1.8	0.4	1.1	0.3	2.5	1.1	—	
	O_2[2]	2.76								
	O_2[3]	13.34	13.3	0.1	—	—	—	—	0.1	
	H_2O[4]	10.00	3.5	—	—	—	7.0	3.0	—	
		73.7	27.8	35.3	1.1	0.3	9.5	4.1	0.1	78.2
2nd phase	gas[1]	2.45	1.2	0.3	0.7	0.2	1.7	0.7	—	
	O_2[2]	1.87								
	O_2[3]	27.40	27.0	0.2	—	—	—	—	0.2	
	H_2O	28.40	9.9	—	—	—	19.9	8.5	—	
		60.1	38.1	0.5	0.7	0.2	21.6	9.2	0.2	70.5

[1] Unburned coke-oven gas.
[2] Oxygen theoretically necessary for the combustion of coke-oven gas.
[3] Total oxygen from the plant, minus that required for combustion in the heater.
[4] Steam utilized for the cooling of the burner in the heater.

Table III. Consumption of Gases for Diverse Converter Processes, Normal Cu M per Metric Ton Pig

Processes	O_2 Theoretical	Afterblows						Totals (Blows + Afterblows)					O_2 Total	Ratio: O_2 Total/ O_2 Theoretical
		Time, Sec	Air	O_2	CO_2	H_2O	Gas	Air	O_2	CO_2	H_2O	Gas		
O_2-H_2O—two afterblows with hot enriched air	51.3	27	30.1	6.3	—	4.2	1.6	74.1	50.9	—	42.6	7.7	80.2	1.56
O_2-CO_2—two afterblows with enriched air	51.1	36	37.3	4.5	—	—	—	115.3	45.2	28.4	—	—	80.8	1.58
O_2-CO_2—one afterblow O_2/CO_2 plus one with enriched air	50.3	38	19.2	8.7	6.4	—	—	98.3	49.0	32.2	—	—	82.5	1.64
O_2-CO_2—two afterblows O_2/CO_2	55.5	35	—	14.0	14.7	—	—	90.8	57.6	48.2	—	—	96.0	1.73

[1] See explanation in text.

Their superheating is accomplished by mixing with the gases from the burner.

Super heated gases are generally used only with oxygen-steam blowing, and with both phases of this process.

Carbon Dioxide Plant: Fume from the blast-furnace stoves is the source of carbon dioxide; it contains 22 pct CO_2, 3 pct O_2, and 75 pct N_2. This gas is compressed to about 6 atm, and cooled to −68°C before entering a counter-current absorption tower with trichloroethylene. Carbon dioxide is dissolved to form a liquid containing 6 pct trichloroethylene, 91 pct CO_2, and 6 pct O_2 and N_2. The liquid is withdrawn, treated at 1.2 atm to eliminate the nitrogen, and then passed into a final tower where the trichloroethylene is separated in a vacuum of 0.18 atm.

The purity of the carbon dioxide thus obtained is about 99.6 pct, the remaining gas being almost wholly oxygen. The yield of carbon dioxide in the process is 81 pct. The installation is supplied with 1600 normal cu m of blast furnace stove fume per hour, and yields 300 normal cu m of carbon dioxide, which is stored in the 1000-cu-m storage tank mentioned previously. Since the consumption of carbon dioxide per metric ton of pig iron varies from 27 to 34 normal cu m, this plant supplies a blast for 200 metric tons of pig iron per day.

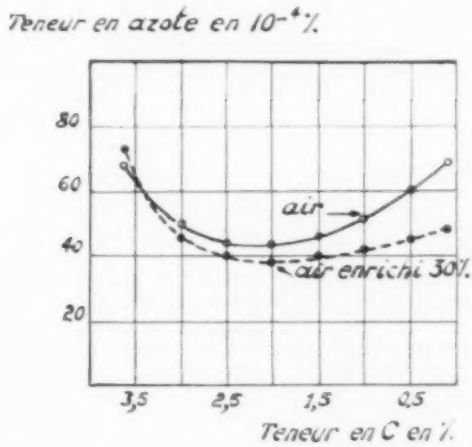


Fig. 1—Variation in the nitrogen content of thomas steel during decarburization in a bottom-blown converter with air and air enriched with oxygen to 30 pct.

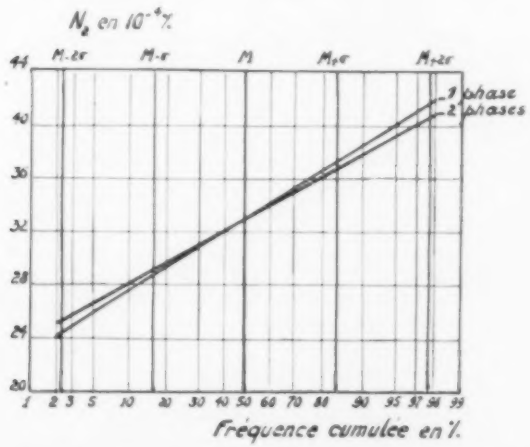


Fig. 2—Nitrogen content of steel blown with oxygen-carbon-dioxide in one and in two phases. Cumulative frequency in percent is shown on the abcissa.

Operating results

Both the oxygen-steam and the oxygen-carbon-dioxide blowing processes have been examined in detail, and the average consumption of gases by constituents is shown in Table I.

The average analysis of desulfurized pig iron charged into the converter for the two blowing techniques is as follows:

	O_2-CO_2	O_2-Steam
C	3.35 pct	3.38 pct
Mn	0.35	0.46
Si	0.20	0.20
P	1.93	1.92

The theoretical oxygen necessary to oxidize completely the carbon, manganese, silicon, and phosphorus is 51.1 and 51.3 cu m per metric ton of pig iron for the two above mentioned pig irons, respectively. Partial combustion and residual oxygen mean that this theoretical value is only relative to the actual consumption.

Nitrogen in steel: Table I shows that the first phase of the oxygen-carbon-dioxide process may be unfavorable in view of the presence of larger quantities of nitrogen and the absence of such gases as CO, CO_2, H_2O, and H_2 which result from superheating as practiced in the first phase of oxygen-steam blowing. Thus, it is possible that the minimum nitrogen content reached in the first phase of the oxygen-carbon-dioxide process is higher than that attained when oxygen-steam are used. However, in view of the lower nitrogen content of the second phase of the oxygen-carbon-dioxide process, this should, in the final analysis, result in the lowest nitrogen content in the finished steel. Practically, the difference in the nitrogen content of steels obtained from the two methods is very slight, Fig. 4.

Operating characteristics of a typical blow from each process is shown in Table II.

Hydrogen effect: When using oxygen-steam, it is important to consider the effect of dissolved hydrogen. This is particularly true in the production of killed steel, where the decrease in the solubility of hydrogen between the liquid and the solid metal

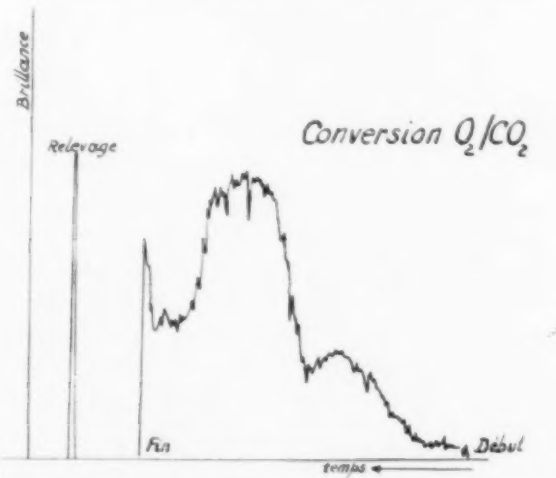


Fig. 3—Variation of the brilliance of the flame in the course of conversion with oxygen-carbon-dioxide. Increasing time is shown toward the left, with an afterblow shown at the extreme left.

results in the evolution of considerable quantities of hydrogen upon solidification. To prevent the formation of blowholes, it has been found necessary to flush the bath with a gas free of hydrogen. This results in a certain reintroduction of nitrogen into the steel, the seriousness of which depends upon the nitrogen content of the gas used.

In the case of oxygen-carbon-dioxide injection, where troublesome dissolved gases present no problem, the use of other gases in the afterblow depends only on economic considerations. This process is, therefore, recommended for producing killed steel with low nitrogen content.

Renitrification: The importance of renitrification in the course of the afterblow should be emphasized. Certain research workers, using enriched air consider it negligible—about 0.0005 pct, while others, using standard air, estimate the value to be 0.0010 pct with 30 sec of blast.

Experience indicates that the afterblow of air enriched to 33 pct results in renitrification of 0.0005 pct from 30 sec of afterblow.

The renitrification between the converter and the casting pit is on the order of 0.0002 pct. The addition of solid ferromanganese, containing 0.022 pct N_2, is partially responsible for this.

Consumption of gases: Table III reviews the consumption of gas per ton of pig iron with separation of the blow itself from the afterblow. The table also shows the *total* oxygen, which is the sum of the oxygen of the air, that produced in the plant, and that from the dissociation of 70 pct of the steam and 80 pct of the carbon dioxide. Because of certain losses, this total is actually somewhat in excess of that amount actually penetrating the bath. Thus, this figure has only relative significance, as in the case of the theoretical oxygen previously calculated, and to which it is compared in the last column of Table III. This leads to the conclusion that with the same number of afterblows with oxygen-enriched air, the relationship between the total oxygen and the theoretical oxygen is not influenced by the nature of the gas used in the blow. Thus, the yield from the oxygen injected is practically the same for the different types of processes.

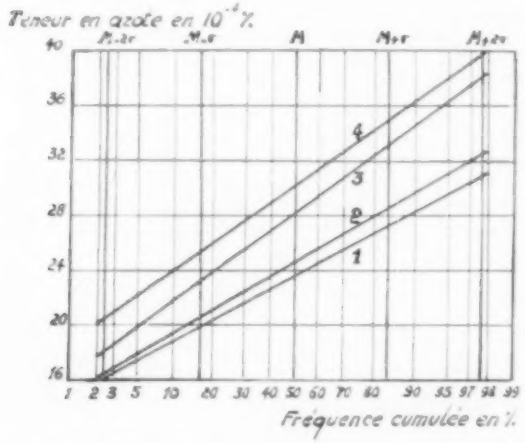


Fig. 4—Nitrogen content of thomas steel obtained by blowing with oxygen-carbon-dioxide (1), oxygen-steam (2), oxygen-carbon-dioxide after intense dephosphorization (3), and the same two gases measured at the end of the cast (4). Abcissa shows cumulative frequency in percent.

Table IV. Scrap Consumption by Two Converter Blowing Techniques

	Pig Iron Analysis, Pct				Scrap, 98 Pct Fe, Kg per Metric Ton Pig	Lime, Kg per Metric Ton Pig	Final Temp, °C
	C	Mn	Si	P			
O_2-CO_2	3.49	0.48	0.33	2.08	52.7	142	1628
O_2-Steam	3.37	0.47	0.29	2.06	15.5	134	1625

Scrap Consumption: Detailed calculations based on the composition of the gases injected would lead to the conclusion that less scrap is consumed in the oxygen-carbon-dioxide process, because of the more endothermic nature of carbon dioxide dissociation. In practice, however, just the opposite occurs.

Furthermore, the first phase of the oxygen-carbon-dioxide is more exothermic than the first phase of the oxygen-steam process, even with heating the gases in the latter to 300° to 350°C. This is a result of the endothermic dissociation of the steam, which is contained in the first phase of only the oxygen-steam process.

From preliminary studies of the two phases of the two converter processes, it appears that scrap consumption is higher when oxygen and carbon dioxide are used, Table IV. The additional scrap required is estimated to be 51.6 kg per metric ton of pig iron. This increased scrap consumption in the oxygen-carbon-dioxide process must be taken into account when comparing the two processes from an economic viewpoint.

Economic considerations: A comparison of Belgian operating and capital costs with those of other countries is of only limited value, and with there being some question of a final determination of the scrap consumption by the two processes, it can only be said that costs for oxygen-steam and oxygen-carbon-dioxide appear relatively parallel.

Conclusions

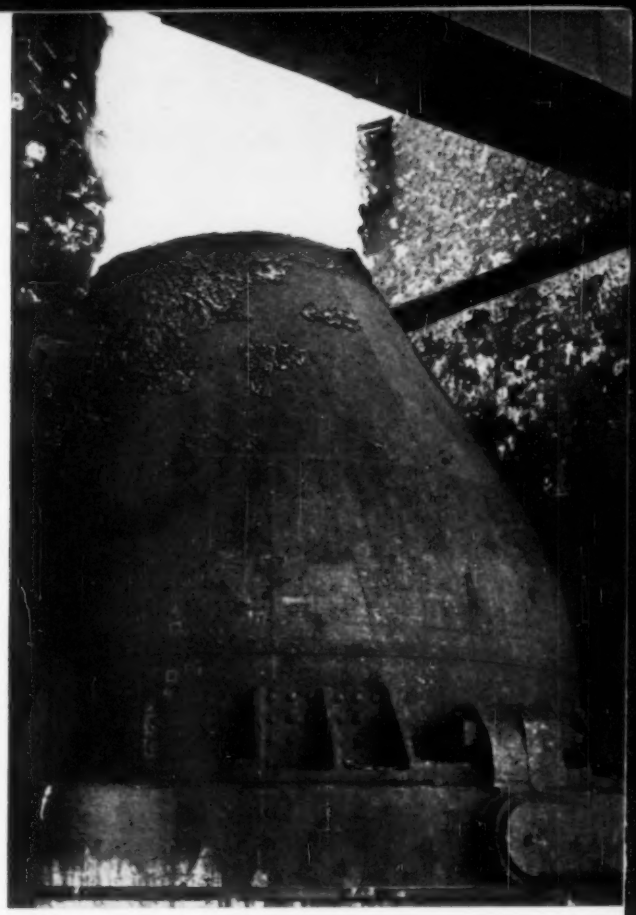
The oxygen-carbon-dioxide process, heretofore considered as more expensive, proves in practice to be at least the equal of the oxygen-steam process when using the two-phase technique and even superior in a one-phase operation. The process is particularly recommended for the production of killed steels, in view of the low humidity of the injected blast and the total absence of gas evolution in the mold.

Higher scrap consumption capabilities tend to minimize the difficulties encountered in the conversion of physically and chemically cold pig iron. Heating of pipes is eliminated and regulation of the gas mixture is simpler and more reliable with oxygen-carbon-dioxide blowing. Moreover, the injection of gases at ambient temperatures, which are practically constant, facilitates thermal control.

The presence of red fume at end of dephosphorization does not seem greatly to impair iron yield.

With regard to nitrogen content of the steel, the two processes are almost equivalent, both in average content and in the spread of values. They guarantee maximum nitrogen values of 0.0040 pct.

These processes hold a well-deserved place among the recently developed techniques for increasing the utilization of steels made in the basic or thomas converters.



LD PRODUCES ALLOY STEELS IN AUSTRIA

Techniques for applying the LD converter to high-carbon steel production were derived during rail steel manufacture at the Donawitz plant of Osterreichisch Alpine Montangesellschaft. They are described here along with examples of various grades of high-carbon alloy steel produced by the process.

by O. Cuscoleca and K. Rosner

FOLLOWING World War II, the rise in the demand for steel led to a rapid increase in world crude steel production. Development work proceeded at full speed toward finding processes which would be best adapted to the available raw materials. One result of this was the LD process, which has enjoyed rapid and widespread acceptance.

The rapid development and expansion of this new process is the result not only of its high efficiency but also of its applicability to a wide range of pig iron compositions for conversion to widely varying grades of steel. The total annual LD capacity now in use is at least 10 million tons.

Composition ranges of pig irons which have been used in modern LD practice indicate the varied charges which may be used:

C	3.60 to 4.60 pct
Si	0.05 to 2.50 pct
Mn	0.30 to 3.50 pct
P	0.08 to 0.50 pct

In addition, H. A. Trenkler has reported satisfactory results using pig iron with phosphorous as high as 2.0 pct.

O. CUSCOLECA and K. ROSNER are technical director and steel mill manager, respectively, for the Osterreichisch-Alpine Montangesellschaft, Leoben, Austria. This paper was presented in June at the the Journées Internationales de Sidérurgie in Liège, Belgium.

Steels produced at Donawitz

A number of LD shops have keyed their production program to the production of low-carbon steels for rolling into plate and sheet. However, at Donawitz a highly diversified rolling program—including rails and heavy structurals, bars, rods, sheet, and plate—necessitates the production of considerable tonnages of quality steel, in addition to the usual

commercial grades. Thus, almost from the start-up of the LD shop, the plant was faced with the problem of producing high-quality steels up to the highest carbon content.

Favorable results obtained in pilot-plant operations weighed heavily in the decision to expand the LD process to the commercial scale at Donawitz. Today, this shop is no longer the sole producer of high-carbon quality steels, since two other European steel firms have adopted LD to similar grades.

To appreciate the full range of possibilities afforded by the LD process, it would be well to understand these characteristics which are important to its success:

1) The LD process is based on ample supplies of pig iron—it represents a refining process similar to that carried on in the open-hearth furnace in that the metal bath is always covered with an oxidizing slag. By the nature of the process, it is possible to reduce the levels of phosphorous, silicon, nitrogen, and oxygen to values that are even lower than those usually achieved in open-hearth practice.
2) Pig iron constitutes the bulk of the charge—therefore it is easy to control closely the presence of undesirable trace elements, such as copper, chromium, and nickel. If the blast furnace burden contains ores free from such elements, the charge to the LD can consist of practically pure hot metal. If, concurrently, cooling scrap of uncontrolled composition is replaced by the same ores, the content of undesirable trace elements in the metal charge can be held to very low levels. This feature raises the possibility of applications for which conventional open-hearth and electric-furnace steels are excluded.
3) The reactions occurring in the LD converter are exothermic—thus, the process is self sustaining with regard to addition of heat. Using conventional grades of pig iron and a hot metal charge at normal heat it is easy to regulate tapping temperatures of the blown steel by adding pre-determined amounts of cooling scrap or ore. The process itself is capable of producing any alloy steel in so far as the heat permits the melting of alloy additions. By using exothermic ferroalloys and pre-heating or pre-melting them, even greater additions may be accomplished.

By taking advantage of these basic principles, the LD process may be adapted not only to making the full range of steels normally melted in the open hearth, but also many electric furnace alloys.

High-carbon steels

The production of high-carbon steels, ranging from commercial grades to heat-treating steels, was initiated at Donawitz beginning with the production of rail steel. Since considerable quantities of this material were produced, the operators were given an excellent opportunity to experiment with various techniques for obtaining the desired results and to evaluate them in practice.

In the production of high-carbon steels by the LD process two basic approaches may be used: a heat may be refined to a low carbon level and recarburized, or the heat may be *caught* at the desired level by terminating the blow at that point.

As is well known, recarburizing can be effected either by the additions of high-carbon hot metal before tapping or by adding carburizing compounds in the ladle at tapping. When using hot metal, the choice is practically restricted to mixer hot metal. Although very economical, this method requires a hot metal which is at the same time low in phosphorous and sulfur and with a carbon-to-manganese ratio compatible with the desired composition. It is quite possible to lower the manganese in the recarburizing hot metal by a pre-blow operation, and to reduce by suitable measures both the phosphorous and sulfur contents to the desired low levels, and thereby enlarge the field of application for this method. Nevertheless, there is a limit to its use, both from technical as well as economic considerations.

This technique was actually used with good results for some length of time, but was finally discarded in favor of catching the carbon at the desired level. The latter technique yields better reproducibility of desired analyses.

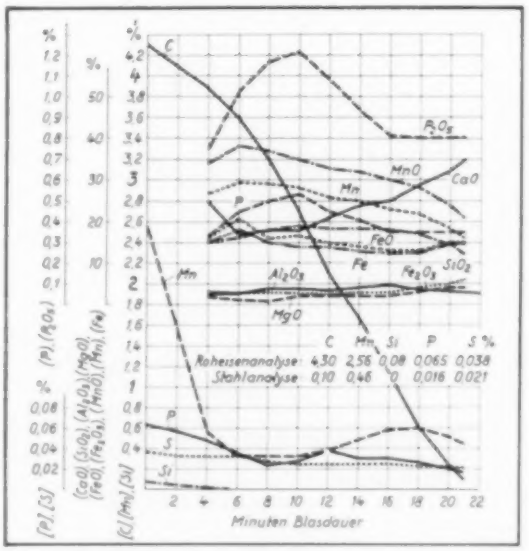


Fig. 1—30 ton LD blow at the Alpine plant in Austria. Abcissa shows minutes of blowing time. "Roheisenanalyse" is pig iron analysis, and "stahlanalyse" is steel analysis.

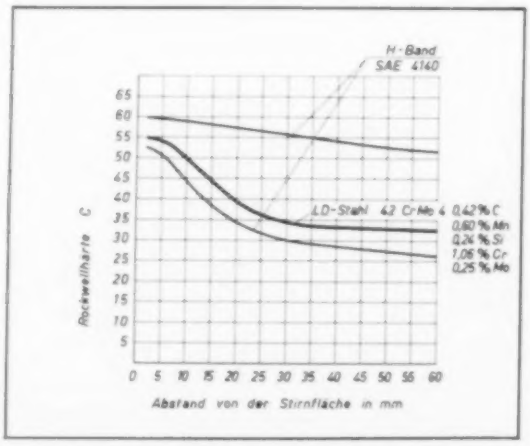


Fig. 2—Hardenability band for 42 Cr Mo 4 steel made by the LD process. Ordinate shows Rockwell C hardness, while abcissa shows distance from end of piece.

The approach of refining the heat to low carbon values, followed by recarburizing the ladle with conventional blocking techniques has not been followed at Donawitz, since it does not provide the desired reproducibility of carbon contents. In addition, there remains some uncertainty about the unfavorable effect of blocking residues. Where high-quality steels are concerned, some scruples seem justified in the use of large quantities of blocking material. However, experience has shown that detrimental effects are not encountered where small additions are used to make final carbon adjustment, Fig. 1

Catching the carbon

There are obvious reasons why the *catch-carbon* technique has always been used at Donawitz: shorter time of blow, lower oxygen consumption, and reduced iron slagging with a lower proportion of oxygen in the bath. Again, it was during the production of rail steels that this fundamentally different approach was tried and tested.

In the course of the well-known reactions in the LD process, the Donawitz pig iron with about 2.5 pct Mn is converted to a 0.6 pct, carbon steel with between 0.70 and 0.90 pct Mn. This is close to usual rail steel specifications. A slight increase in manganese is accomplished, if necessary, by ferromanganese additions in the converter. A heat sheet for such an analysis is shown in Table I.

This technique is well suited to the production of rail steels conforming with railway specifications in different countries. No difficulty is encountered in meeting the ASTM requirements, which call for a maximum of 0.82 pct C and maximum of 1.0 pct Mn.

In order to make the catch-carbon technique generally applicable, it was necessary to work out a method to determine the desired end point of the blow with sufficient accuracy. At this time, there exists no measuring device to indicate to the steelmaker the progress of refining reactions in the converter. However, experimentation in this direction is currently going on at Donawitz. Meanwhile, the time of blowing is taken as a guide. In practice, with a given hot-metal composition, the time of blowing provides a good working basis for the catch-carbon technique if the oxygen input is closely controlled by means of pressure-insensitive precision flow meters. However, about 8 pct of the heats will come off too high in carbon and the remainder will come within the desired analysis either as refined or with slight carburizing.

Thus, it becomes advisable to take a flash analyses for carbon and manganese. By using rapid analysis, reproducibility will vary from 90 to 99 pct, depending on the analysis limits for carbon and manganese. For example, in a group of rail steel

Table I. Rail Steel

	C	Mn	Si	P	S	N_2
Specification	0.50 to 0.55	0.90 to 1.10	0.15 to 0.20	Max 0.050	Max 0.050	— —
Obtained	0.55	0.98	0.20	0.016	0.018	0.004
Charge 6 min	Pig-iron: 33,200 kg Scrap: 2,850 kg Roll scale: 500 kg Lime: 4.5 pct SiO_2: 1.2 pct					
Refining 16 min	Iron: 4.22 pct C, 2.47 pct Mn, 0.18 pct Si, 0.063 pct P Slag: 48.12 pct CaO, 1.18 pct MgO, 10.90 pct SiO_2, 9.70 pct Fe, 11.21 pct Mn					
Sampling 7 min **Deslagging**	Quick analysis: 0.49 pct C, 0.95 pct Mn 1630°C Fe-Mn addition					
Tap 2 min	C-correction, Fe-Si and Al additions					

Table II. Rail Steel

	C	Mn	Si	P	S	N_2
Specification	0.50 to 0.55	0.90 to 1.10	0.15 to 0.20	Max 0.050	Max 0.050	— —
Obtained	0.55	0.96	0.17	0.027	0.016	0.004
Charge 6 min	Pig-iron: 33,100 kg Scrap: 1,100 kg Roll scale: 500 kg Lime: 7 pct SiO_2: 0.9 pct Fluorspar: 0.6 pct					
1st Refining 10 min **Sampling** 6 min	Iron: 4.07 pct C, 1.98 pct Mn, 0.42 pct Si, 0.51 pct P Quick analysis: 2.30 pct C, 0.30 pct Mn, 0.125 pct P					
Deslagging	Additions: Lime: 3 pct SiO_2: 0.8 pct Fluorspar: 0.3 pct					
2nd Refining 7 min	Slag analyses: (1) CaO 40.54 pct, MgO 2.53 pct, SiO_2 19.86 pct, Fe 4.98 pct, P_2O_5 7.83 pct, Mn 14.70 pct (2) CaO 52.14 pct, MgO 2.01 pct, SiO_2 16.24 pct, Fe 7.45 pct, P_2O_5 5.61 pct, Mn 7.00 pct					
Sampling 7 min **Deslagging**	Quick analysis: 0.52 pct C, 0.44 pct Mn, 0.029 pct P 1630°C Fe-Mn addition					
Tapping 2 min	Fe-Si and Al additions					

Table III. Time Cycles for the Production of Different Types of LD Steel

Time in min for steel type	1	2	3	4	5	6	7
Charge: Pig-iron	6	6	6	6	6	6	6
Scrap							
Additions							
Refining	20	20	18	18	16	8	8
Intermediate deslagging	—	—	—	—	—	10	10
Refining	—	—	—	—	—	8	8
Recarburization with pig-iron	—	—	5	—	—	—	—
Tapping: Sampling							
Deslagging							
Converter additions	6	8	8	9	9	9	14
Tapping							
Total	32	34	37	33	31	39	44

1. Low-carbon rimming steel.
2. Low-carbon killed steel.
3. High-carbon steel, recarburized with pig-iron.
4. High-carbon steel, recarburized in ladle.
5. High-carbon steel, catch-carbon.
6. High-carbon steel, catch-carbon with intermediate slagging from high-P or high-Mn pig-iron.
7. High-carbon alloy steel.

heats with rather close limits of 0.50 to 0.55 pct C and 0.90 to 1.10 pct Mn, reproducibility averaged 93.6 pct. The time lost during flash analyses is approximately 4 min per heat. By using some form of spectroscopic analysis, this time might be reduced considerably.

Low Mn from high Mn

There was yet another problem to be solved if the catch-carbon technique was to prove universally acceptable. This was the production of a low manganese steel from a high manganese hot metal. The solution is simple, as closer inspection of the course of reactions will reveal, Fig. 1. At the point where there is least manganese in the bath, part of the slag is tapped so as to prevent dissolution of manganese by the bath later in the blow. This operation takes about 6 min to complete. It will be further illustrated by the case of a heat intended for conversion to patented wire. The same method is also employed in the production of tool steels, and when blowing higher phosphorous pig irons (Table II).

Table IV. Case Hardening Chrome Steel 15 Cr 3

	C	Mn	Si	P	S	Cr	N_2
Specification	0.12 to 0.18	0.40 to 0.60	0.20 to 0.35	Max 0.025	Max 0.025	0.60 to 0.90	—
Obtained	0.13	0.47	0.29	0.012	0.020	0.73	0.005
Charge 6 min	Pig-iron: 33,100 kg Scrap: 2,400 kg Roll scale: 300 kg Lime: 5 pct SiO_2: 1.2 pct						
Refining 20 min	Iron: 4.18 pct C, 2.28 pct Mn, 0.12 pct Si Slag: 38.70 pct CaO, 2.92 pct MgO, 8.37 pct SiO_2, 14.50 pct Fe, 14.48 pct Mn						
Sampling	Quick analysis: 0.08 pct C, 0.45 pct Mn						
Deslagging 7 min	1675°C						
Settling 5 min	Fe-Cr addition						
Tapping 2 min	Additions: Fe-Si and Al						

Table V. Case Hardening Cr Mn Steel, 16 Mn Cr 5

	C	Mn	Si	P	S	Cr	N_2
Specification	0.14 to 0.19	1.00 to 1.30	0.20 to 0.35	Max 0.025	Max 0.025	0.80 to 1.10	—
Obtained	0.15	1.15	0.23	0.013	0.014	0.86	0.005
Charge 8 min	Pig-iron: 32,600 kg Scrap: 2,500 kg Roll scale: 300 kg Lime: 5.0 pct SiO_2: 1.2 pct						
Refining 20 min	Iron: 4.37 pct C, 2.24 pct Mn, 0.18 pct Si Slag: CaO 38.00 pct, MgO 3.77 pct, SiO_2 10.00 pct, Fe 15.44 pct, Mn 12.44 pct						
Sampling Deslagging 7 min	Quick analysis: 0.08 pct C, 0.39 pct Mn 1700°C						
Alloys 5 min	Fe-Mn and Fe-Cr additions						
Tapping 2 min	Additions of Fe-Si and Al						

An evaluation

On the strength of experience gained during the production of about 100,000 tons of rail steel, as well as sizeable quantities of other higher-carbon steels, a definite evaluation of the methods discussed with respect to economy and practicability can be given here. It should be pointed out that all high-carbon heats have been made at the Donawitz LD shop using the catch-carbon technique for a considerable time. Even with the time losses involved, flash analyses are justified by all these factors: steel quality, reproducibility of analyses, favorable yield, and absence of the need for equipment to treat recarburizing hot metal.

A comparison table of heat times is included, (Table III) to illustrate the production rates which may be obtained in the LD process when making various grade of steel. The heat times given here correspond to those encountered in actual practice, and are intended to give an idea of the mean pro-

Fig. 3—Hardness test pieces of 80 Cr V 2 tool steel. Hardening temperatures from left to right (top and bottom row) in °C are as follows: 760, 780, 820, 840, 860, and 900.

Table VI. Cr Alloy Heat Treating Steel 41 Cr 4

	C	Mn	Si	P	S	Cr	N_2
Specification	0.38 to 0.44	0.60 to 0.80	0.20 to 0.35	Max 0.025	Max 0.025	0.80 to 1.20	—
Obtained	0.40	0.79	0.25	0.018	0.016	0.82	0.004
Charge 4 min	Pig-iron: 36,100 kg Scrap: (none) Roll scale: 300 kg Lime: 4.4 pct SiO_2: 1.0 pct Fluorspar: 0.2 pct						
1st Refining 9 min	Pig-iron: 4.12 pct C, 2.82 pct Mn, 0.19 pct Si 1st slag: 36.46 pct CaO, 3.25 pct MgO, 17.30 pct SiO_2, 7.62 pct Fe, 20.60 pct Mn						
Sampling Deslagging 6 min	Quick analysis: 2.38 pct C, 0.63 pct Mn Additions: Lime: 2 pct SiO_2: 0.3 pct						
2nd Refining 9 min	2nd slag: 49.01 pct CaO, 4.47 pct MgO, 10.70 pct SiO_2, 11.98 pct Fe, 11.62 pct Mn						
Sampling Deslagging 7 min	Quick analysis: 0.37 pct C, 0.58 pct Mn 1640°C						
Settling 5 min	Fe-Mn and Fe-Cr additions						
Tapping 2 min	Additions of Fe-Si and Al						

ductivity of the LD process under different operating conditions. Time savings might well be effected by replacing the scrap charge with ore, by introducing spectroscopic analysis, and by reverting to taphole furnaces such as those introduced by Dofasco.

High-carbon alloy steels

Starting from established practice for plain carbon steels, the Donawitz LD shop proceeded to adopt this process to low-alloy steels. In view of the purity of LD carbon steels and the good reproducibility of specified carbon and manganese ranges, no difficulties were anticipated. The results of future operations confirmed this prediction. Among the steels produced to date, are case-hardening and heat-treating grades, low-alloy tool steels, bearing steels, and electrical alloys.

Hot metal is drawn from the mixer with desulfurization practices only when necessary. The temperature of the converter charge is adjusted with suitable scrap additions. The lime charge consists of the conventional lumpy material. In cases where rapid slag formation is desired, fluorspar is added, but fluorspar fluxing may be omitted if limestone fines of uniform size or pulverized limestone is blown in. A normal heat size is about 36 tons.

Operating practice follows high-carbon steel production, with exceptions as noted. The necessity of melt-in alloy additions requires maintaining high end-temperatures. Steel is invariably bottom poured into molds grouped four to a plate. The 4-ton ingots pass immediately after stripping to the soaking pits.

Table VII. CrMo Alloy Heat Treating Steel 42 Cr Mo 4

	C	Mn	Si	P	S	Cr	Mo	N_2
Specification	0.38 to 0.45	0.50 to 0.80	0.15 to 0.30	Max 0.025	Max 0.025	0.90 to 1.20	0.15 to 0.25	—
Obtained	0.42	0.60	0.24	0.015	0.020	1.06	0.25	0.005

Charge 4 min	Pig-iron: 35,200 kg Scrap: (none) Roll scale: 300 kg Lime: 5.5 pct SiO_2: 1.4 pct Fluorspar: 0.3 pct
Refining 17 min	Iron: 4.26 pct C, 1.88 pct Mn, 0.10 pct Si Slag: CaO 59.66 pct, MgO 4.70 pct, SiO_2 13.46 pct, Fe 8.18 pct, Mn 15.82 pct
Sampling Deslagging 7 min	Quick analysis: 0.29 pct C, 0.60 pct Mn 1640°C
Settling 5 min	Fe-Cr and Fe-Mo additions
Tapping 2 min	Additions: Fe-Si and Al

Table VIII. Band-saw Steel 80 Cr V 2

	C	Mn	Si	P	S	Cr	V	N
Specification	0.77 to 0.85	0.40 to 0.60	0.25 to 0.35	Max 0.025	Max 0.025	0.50 to 0.60	0.20 to 0.30	—
Obtained	0.81	0.58	0.25	0.017	0.019	0.50	0.24	0.004

Charge 4 min	Pig-iron: 35,300 kg Scrap: (none) Roll scale: 300 kg Lime: 4.5 pct SiO_2: 1.2 pct Fluorspar: 0.2 pct
1st Refining 9 min	Iron: 4.01 pct C, 1.78 pct Mn, 0.25 pct Si 1st slag: CaO 29.15 pct, MgO 1.10 pct, SiO_2 18.82 pct, Fe 8.62 pct, Mn 22.80 pct
Sampling Deslagging 6 min	Quick analysis: 2.29 pct C, 0.30 pct Mn Additions: Lime: 1.7 pct SiO_2: 0.6 pct Fluorspar: 0.3 pct
2nd Refining 7 min	2nd slag: CaO 64.74 pct, MgO 1.20 pct, SiO_2 13.46 pct, Fe 6.78 pct, Mn 8.60 pct
Sampling Deslagging 7 min	Quick analysis: 0.69 pct C, 0.56 pct Mn 1610°C
Settling 5 min	Fe-Cr addition
Tapping 2 min	Additions of Fe-Si, Fe-V, and Al

Case-hardening chromium steel 15 Cr3—Table IV

The single-slag technique is used when low carbon and medium manganese contents are called for. A preliminary sample, taken after 20 min of blow, showed carbon and manganese of 0.08 pct and 0.45 pct, respectively. Adding only about 6.5 pct, cooling scrap held the temperature at 1675°C for tapping. This means that it is not feasible to add preheated ferrochrome. A settling time of five min for alloying additions had been found satisfactory. Heats of this type take 40 min to make. This is 8 min or 25 pct longer than the heat time for rimming soft steel. Test results show that standard specifications are easily met. With regard to hardenability, carbide formation, and inclusions, this steel is comparable to that produced in the open-hearth or electric furnace.

Case-hardening Cr-Mn Steel 16MnCr5—Table V

Analysis specifications clearly call for single-slag operation. Heat time remains 40 min. End-temperature was 1700°C, and additions of ferromanganese and ferrochrome can be made cold in the furnace. Settling time was five min, and the yield of manganese and chromium corresponded to open-hearth practice. Test results were well within the requirements established for open-hearth or electric-furnace steels.

Heat treating chrome steel 41Cr4—Table VI

Because of the different manganese contents in the hot metal charge and the desired analysis, some of the slag was tapped after blowing for 9 min. Thus, excessive manganese pick-up from the slag at the end of the blow was avoided. Just before slag-off, flash analysis showed 2.38 pct C and 0.37 pct Mn. Blowing resumed 6 min later; 9 min after this an analysis indicated carbon to be 0.37 pct and manganese, 0.57 pct. Although the temperature was low (1600°C), ferrochrome was added cold. Final heat time was 42 min. The time loss for slag-off is partly compensated for by a shorter charging cycle (scrap additions omitted) and by a shorter time of blow (catching the heat at a high carbon level). When working low-manganese pig irons, the intermediate slag-off can be avoided and the heat time reduced to 36 min. The quality of this steel is on a par with the same grade produced in the open-hearth or electric furnace.

Heating treating 42CrMo4 steel—Table VII

This specification indicates single-slagging as the most convenient method here. After 17 min of the blow, the heat contained 0.29 pct C and 0.60 pct Mn and the temperature was 1640°C. At this point, ferromanganese and ferrochrome were added cold. Five min were allowed for settling, then ferrosilicon and aluminum were added while the heat was tapped. Heat time was 37 min. Because of the higher carbon, the time of blow is shorter and overall heat time exceeds that for rimming soft steel by only 5 min. The hardenability band for this steel, Fig. 2, is well within specified values, as were impact and hardness values.

Table IX. Cr-alloy Ball-bearing Steel

KLS	C	Mn	Si	P	S	Cr	N_2
Specification	0.98 to 1.08	0.30 to 0.50	0.25 to 0.35	Max 0.020	Max 0.020	1.40 to 1.65	—
Obtained	1.02	0.54	0.25	0.013	0.018	1.57	0.003
Charge 4 min	Pig-iron: 35,400 kg Scrap: (none) Roll scale: 600 kg Lime: 4 pct SiO_2: 0.6 pct Fluorspar: 0.3 pct						
1st Refining 8 min	Iron: 4.29 pct C, 2.30 pct Mn, 0.33 pct Si 1st slag: CaO 33.60 pct, MgO 2.00 pct, SiO_2 18.20 pct, Fe 9.52 pct, Mn 20.80 pct						
Sampling Deslagging 10 min	Quick analysis: 2.85 pct C, 0.71 pct Mn Additions: Lime: 4 pct SiO_2: 0.7 pct Fluorspar: 0.3 pct						
Alloying	200 kg 75 pct Fe-Si						
2nd Refining 8 min	2nd slag: CaO 49.55 pct, MgO 5.08 pct, SiO_2 16.50 pct, Fe 7.58 pct, Mn 7.52 pct						
Sampling Deslagging 7 min	Quick analysis: 0.85 pct C, 0.57 pct Mn 1605°C						
Settling 5 min	Fe-Cr addition						
Tapping 2 min	Additions of Fe-Si and Al						

Table X. Dynamo Sheet Steel

	C	Mn	Si	P	S	N_2
Specification	Max 0.04	Max 0.20	2.20 to 2.40	Max 0.025	Max 0.020	—
Obtained	0.03	0.18	2.25	0.009	0.015	0.002
Charge 6 min	Pig-iron: 31,100 kg Scrap: 4,400 kg Roll scale: 500 kg Lime: 5 pct SiO_2: 1 pct Spar: 0.3 pct					
1st Refining 8 min	Iron: 4.23 pct C, 2.14 pct Mn, 0.18 pct Si					
Sampling Deslagging 10 min	Quick analysis, 2.50 pct C, 0.46 pct Mn Additions: Lime: 3 pct SiO_2: 0.6 pct Fluorspar: 0.3 pct					
2nd Refining 15 min	Slag analysis: 37.5 pct CaO, 2.7 pct MgO, 7.5 pct SiO_2, 23.8 pct Fe, 6.6 pct Mn					
Sampling 6 min **Deslagging**	1650°C					
Tapping 2 min	Additions: Fe-Si and Al					

Cr-V tool steel 80CrV2—Table VIII

On account of the relatively low manganese content specified for this steel, a partial slag-off was made after 9 min of blowing, even with a low (for Donawitz) level of 1.78 pct Mn in the hot metal. At slag-off, the bath tested 2.29 pct C and 0.30 pct Mn. After supplementary slag forming additions, the blow was continued and the heat caught after 8 min. With the temperature at 1610°C, carbon and manganese stood at 0.69 pct and 0.56 pct, respectively. Ferrochrome additions were allowed to settle for 5 min, and the heat was tapped with additions of ferrosilicon, ferrovanadium, and aluminum. The heat time was 41 min. Hardness interval test pieces clearly indicate the beneficial effect of vanadium on hardenability, Fig. 3.

Chrome bearing steel 100Cr6—Table IX

The first slag was run-off completely after 8 min blow time. Following addition of another set of slag-forming materials and 440 lb of ferrosilicon (75 pct) to make up for heat losses, the blow was continued for another 8 min. At this point, the flash analysis showed 0.85 pct C and 0.57 pct Mn. The bath temperature was 1605°C. Ferrochrome was added in the converter and 5 min settling time was allowed. The freedom from inclusions was determined by means of *Diergartens* scale and showed a value of 55, which is quite satisfactory. Hardening characteristics were good.

Dynamo sheet steel—Table X

Working with the high-manganese Donawitz hot metal, the first slag was run off after 8 min of blowing in order to arrive at the low specified manganese content in the finished steel. Flash analysis before run-off showed 2.50 pct C and 0.46 pct Mn. Blowing was continued for another 15 min to give the steel of this final analysis: 0.03 pct C, 0.15 pct Mn, 0.009 pct, and 0.014 pct S. The slag contained 24 pct Fe total, which is comparatively low. The usual ladle additions of ferrosilicon and aluminum were made. This steel was of excellent purity. Test results on 0.5 mm (0.02 in.) sheet showed watt losses (VIO) averaging less than 2.0 w per kg (0.9 w per 16).

Test runs on steels with over 3 pct Si, such as are usually made only in the electric furnace, have shown that the LD process holds some promise even in this field.

Conclusions

From the examples given here, it should be clear that the grades of steel which can be made in the LD converter range from extremely soft grades to steels containing as much as 1 pct C. This wide range is bounded by magnetic soft iron at one end and by low-alloy tool steels at the other. The production of non-alloyed soft magnetic iron in the LD converter would require special measures with regard to oxidation, deoxidation, and teeming, if present exacting requirements for magnetic materials are to be met.

EDUCATION IN PROCESS METALLURGY

The best method of teaching process metallurgy is an analytical approach, based on a sound foundation of science and engineering principles. The unit process concept should be used to the extent that it has been developed.

by W. O. Philbrook

THE practice of process metallurgy in industry is primarily engineering in nature. It may embrace a wide variety of situations, and the spectrum is ever broadening as additional metals come into commercial use and new processes are developed for the extraction or refining of the commoner ones. A sound background in science and engineering principles appears to be the most effective basis for training students to cope with the problems that will face them in the future.

The field of process metallurgy

Since usage varies, it will be helpful to start by defining the field of process metallurgy. Broadly speaking, this covers the extraction of metals from suitable ores or concentrates, refining and alloying them, and delivering them in appropriate form as primary metals for further fabrication or processing. This does not exclude mineral beneficiation when it is practiced by those who are primarily metallurgists and as an integral part of the extraction process. At the other end, there is some overlap in interests with other branches of metallurgy. The solidification of metals and the control of ingot structure are within the legitimate domain of the process metallurgist; yet many who proclaim themselves to be physical metallurgists take a keen interest in the freezing process because of its significance in relation to the structure and properties of metals. Similarly, some metallurgists like to classify the foundry arts as *metal processing* in conjunction with welding, forging, rolling, and other methods of fabrication. There is no need to draw dividing lines too sharply, because this discussion relates primarily to the central aspects of process metallurgy.

An approach to metallurgical education

Considering that some 80 chemical elements are metallic, or sufficiently so to be of interest to metallurgists, and that more and more of these are assuming commercial importance each year, it is evident that the encyclopaedic method of teaching the process metallurgy of each element individually is hopelessly inefficient. A student trained in this fashion only ten years ago would find himself today under some handicap in dealing with recent innovations in a supposedly *stable* industry such as steelmaking, and he would be ill prepared indeed to cope with the extractive metallurgy of commercially pure zirconium or vanadium. It is essential that our students be trained, not in yesterday's arts, but in the principles and analytical techniques that will enable them to modify and improve existing methods, develop new processes, and analyze proposed ones to determine whether or not they have sufficient promise of commercial success to warrant the cost of development. How should metallurgical education be approached in order to develop these abilities?

One might subdivide the field of extractive metallurgy into several classifications, such as hydrometallurgy, electrometallurgy, and pyrometallurgy, with the thought in mind of teaching the principles of each category. But further consideration shows the inadequacy of this approach. Hydrometallurgy may culminate in chemical reduction or electrodeposition. Electrometallurgy may be practiced using aqueous electrolytes or fused salts of several kinds. And the methods of pyrometallurgy are legion, embracing various homogeneous and heterogeneous reactions of selective oxidation, selective reduction, or halogenation, at pressures ranging from less than a micron of mercury to several atmospheres. Clearly, a still more fundamental approach is needed.

Unit process or operations approach

The method that has been adopted by many of the leading schools of the U.S. and Canada is patterned after the solution developed by the chemical engineers some three decades ago to meet a similar problem. It is commonly called the *unit process* or *unit operations* approach. The technique is to determine, by suitable analysis, a body a underlying engineering principles and a set of unit operations and processes that occur commonly in most of the important engineering processes. The salient features of each of these unit actions are then analyzed intensively so that their characteristics and controlling features may be clearly understood. Real processes may then be created by adding the appropriate unit steps in sequence, like building blocks,

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to build up the flow sheet for the particular process. Thereafter, only the special limitations set by factors peculiar to the specific process need be given individual attention The latter might include such factors as corrosive conditions, operating temperatures, or pressure levels that would limit materials of construction, specific rate-determining factors, etc. The strength of this approach is obvious. It concentrates the time and attention of the student on fundamentals that are common to a variety of present as well as future processes, develops his powers of analysis, and leaves the acquiring of specific details of the contemporary art to be accomplished more quickly and effectively in the specific industry where he elects to practice.

The distinction that is commonly made between *unit operations* and *unit processes* is that the former are purely mechanical operations that may alter the size, shape, or location of materials but not the nature of the substances, whereas unit processes involved either chemical reactions or phase changes or both. Most of the concentrating procedures of ore dressing may be subdivided into unit operations, while extraction of metals from their ores is largely concerned with unit processes, but neither of these illustrations should be taken to be exclusively of one type. For the present purpose, *unit processes* will be employed as a generic term that may sometimes include unit operations.

In the application of the unit processes approach to the teaching of process metallurgy, the details of method and the degree of emphasis will vary somewhat from school to school. Unfortunately, the metallurgical profession has not yet advanced to the same stage as chemical engineering in the definition and precise analysis of our unit processes, and text books appropriate for this style of teaching are sorely needed. This paper is intended partly as a summary of the present status and partly as an opinion on what needs to be done in this regard.

The most important quality to be instilled into our students is the habit of approaching a problem always with questions such as these: "What are the limiting features of this process that determine the optimum size of equipment, the rate of throughput, the efficiency of the process, and the quality of the product? Are these controlled by fluid flow, heat transfer, mass transport, chemical kinetics, or equilibrium considerations, or by purely mechanical or structural limitations? What are the economics of this process in relation to the demand for the product or in comparison with alternative methods of accomplishing the same result?" Generally, the technology must be understood before the economic question becomes meaningful.

Grounding in fundamentals of science

The primary tools for such analytical thinking are, of course, a good grounding in mathematics, physics, and chemistry. These sciences are equally essential to physical metallurgy and to other scientific and engineering fields. Almost universally they form the technical core of the first two years of study at all engineering schools.

It is most important that the training in chemistry for all metallurgists be carried through physical chemistry. This should be strongly directed toward thermodynamics, but not to the exclusion of electrochemistry, surface chemistry and kinetics. A sound philosophy, applied at Carnegie Institute of Technology and elsewhere, is that the fundamentals of physical chemistry should be taught in the chemistry department by professional chemists who will be up to date with the broad field. This basic training should then be supplemented by specific applications in the field of process or physical metallurgy, as the case may be, taught in the metallurgy department by men who are abreast of the current research in their own specialties. It is a particularly fortunate arrangement if the curriculum can be coordinated so that at least some of the metallurgical applications follow closely behind and almost concurrently with the teaching of fundamentals by the chemistry department—an aim which has been achieved with some success at Carnegie.

And basic engineering principles

Parallel with the fundamental sciences there is a body of information and techniques which may be called basic engineering principles. These are also shared with other engineering fields, notably chemical and mechanical engineering. Subjects included are dimensional analysis, fluid flow, heat transfer under both steady and unsteady-state conditions, mass transport, applications of chemical stoichiometry to industrial material balances, applications of thermochemistry, together with material balances and heat transfer, to heat balances and to the combustion and efficient utilization of fuels, and applications of thermodynamics and phase diagrams to systems of importance in process metallurgy. Some of these topics could be taught with a basic approach for students in several related fields, but others are best handled by direct application to a specialized field of engineering. In the arrangement of the curriculum at Carnegie Tech it has been found most practical to handle all of these subjects in a course within the Metallurgical Engineering department.

The nature of materials and processes

These are the basic tools of science and engineering that are available for analysis of metallurgical processes. In addition, the student must be taught something about the nature of the materials that he will deal with. He must know something about refractories, not only because they are the commonest materials of construction, but also because of their inevitable interactions to some degree with slags, mattes, or metals. He must know about the structure of molten metals, slags, mattes, and fused salts, as far as we are able to teach him at the present time. Frequently, the best way to impart this information is in conjunction with the behaviors of these materials in sepcific processes.

Another useful method of systematizing the analysis of a process is in terms of the types of reactions taking place. Process metallurgy commonly deals with gas-solid, gas-liquid, liquid-liquid, and solid-liquid reactions. There is much in common in the principles of gas flow and in gas-solid reactions in shaft furnaces of various types, and much that can be said in common of liquid-liquid reactions in matte-smelting, slag-metal refining, and so on. The student's analytical ability will be sharpened if he is trained to see the points of similarity among processes and the reasons for specific differences peculiar to a given set of operating conditions.

A basic consideration always is whether or not a given process or separation is thermodynamically feasible. It is profitable to begin the study of real processes with an examination of the free energy

diagram for oxides to establish first a concept of the relative stability of the pure oxides, and then to develop later the ways in which activities come into play in the behavior and control of slag refining and other metallurgical processes. Similarly, the free energy diagram for sulfides provides a start for roasting and matte-smelting processes, and the free-energy diagram for chlorides is the basis for chlorine metallurgy.

The next step beyond thermodynamic limitations is the role played by kinetics and transfer processes. Is a given process inherently limited by the rate at which heat can be supplied to or removed from the reaction zone, by convective transport within a solid lump, or by resistance to gas flow in a granular bed or by slugging or carry-over in a fluidized bed? Some processes can be fairly adequately engineered from thermodynamics, stoichiometry, and heat transfer alone, while others are exceedingly complex. Unfortunately, many of the processes of extractive metallurgy have not yet been reduced to a systematic unit process basis, so we can not yet do as effective a job as we should like in teaching them.

Limitations of four-year curriculum

In addition to the limitations forced by the present state of understanding of our more complex processes, there is inevitably a problem of time limitation in a four-year curriculum. For this reason, it is necessary to design courses so that selected illustrations of various limiting considerations are emphasized to give a fairly well-rounded survey rather than a completely comprehensive treatment for the metallurgy of each element. These are built into a framework of the process metallurgy of the more important commercial metals, but with considerable emphasis on points of similarity and difference and on the analysis of new processes or adaptions of current interest.

There are a few places in which the current state of knowledge of the art is weak and where emphasis needs to be placed in future research as well as teaching. For very good reasons, the first research efforts in systems of interest to process metallurgy were heavily directed toward thermodynamics and determinations of activities of species. While this work is far from finished, we are rather well supplied with enough information to present good examples of these techniques to students and to fit them for making further use of the literature as it develops. On the other hand, our working knowledge of kinetics and transfer processes in process metallurgy is much less advanced. We probably have not made as much use as we should of the methods of handling mass transfer processes that are employed by chemical engineers, and we need a great deal of additional research on the kinetics of the gas-solid, gas-liquid, and liquid-liquid processes of reduction, smelting, and refining that are peculiar to process metallurgy.

Complexities of processes

When one attempts to make some use of chemical engineering data, he is struck by the great complexity that we impose upon ourselves in some processes. For example, metallurgical engineers will either have to work out the problems of gas flow and mass transport in heterogeneously stratified and segregated beds for themselves, or else modify the charging and operation of shaft furnaces to approach more closely the uniform beds for which some data are available from chemical engineering literature. As long as metallurgists are constrained to operate at high temperatures and with refractory containers that inevitably participate to some degree in the process, they will be faced with the necessity of dealing with complex rather than simple systems and with somewhat instable geometries. It is a knowledge and ability to cope with such situations—by art if not by science—that distinguishes our profession from ordinary chemists or engineers.

There are several areas in which more emphasis will be needed in the future in order to keep metallurgical training in step with industrial practice. It appears that fluidized bed techniques are becoming standard in several branches of process metallurgy, and vacuum melting and other separations carried out at reduced pressures are assuming greater importance. An area that has been rather badly neglected by American process metallurgists until recently is the use of the principles of dimensional analysis, pilot plants, and scale-up factors. These principles are inherently needed in the practical application of any laboratory studies other than equilibrium ones; and they become vital in the use of pilot plant equipment to study existing processes or develop new ones. We must prepare our students to accept responsibility in these fields or find our job taken over by other branches of engineering that are more alert to these needs. Somehow, we should also contrive to keep our students aware of the increasing importance of statistical techniques for planning experiments and analyzing data and of the use of digital and analogue computers for data processing and analysis.

It is fairly obvious that all of these things can not be done well in a four-year curriculum, so there will be increasing emphasis on graduate work for those who have the ability to assume full professional stature.

Importance of economic considerations

The economic side of process metallurgy deserves a few words. Whether or not the details of cost analysis are taught, it is essential that students be made aware of the fact that, when technology is adequate, the final decision on the selection of a process depends upon economics. Mundane considerations of cost may tend to be submerged in an academic atmosphere devoted to the search for truth and knowledge, but economics is a primary concern of the practicing engineer in industry. The minimum responsibility is to forewarn the student that he will be expected to assume such responsibility and to develop in him an economic viewpoint in a qualitative if not a quantitative way.

In summary, it is the author's opinion that the best method of teaching process metallurgy, as practiced by leading American and Canadian schools, is with an analytical approach, based on a sound foundation of basic sciences, physical chemistry, and engineering principles. The unit process concept is used to the extent that it has been developed, and the attempt is made to analyze metallurgical processes critically to discover their significant controlling features and to search for points of similarity and difference among related processes. This is considered the most effective way to train students to analyze and develop new processes for the future of a vital and expanding metallurgical industry.

EDITORIAL

MEMBERSHIP GOALS,

Why they must be met.

by D. C. Hilty,
Metallurgical Society
Membership Chairman

The recent formation of new technical committees in all divisions of The Metallurgical Society of AIME, as well as the expanded publications program, attest to the dynamic nature of the metal producing and using industries. At the same time, it foreshadows probably the greatest period of potential growth in Metallurgical Society activities, with respect to meetings, publications, and opportunities for participation by individual members on a professional basis.

In order to have real growth in Society activities, however, it is necessary to do more. There must be substantial growth in the number of members, as well as in the variety of interests. New technical committees, as well as older ones, depend for their effectiveness on the continuing development of interest in new phases of metallurgy and in new directions in the *classical* metallurgical fields. Thus, effective functioning of Society activities requires that membership increase rapidly in the months ahead. Otherwise, regardless of improved quality and extent of meetings and publications, the Metallurgical Society's position of the *leading professional society* in the metals field will become increasingly precarious. Without substantial increases, membership will comprise an ever decreasing proportion of the total professional men in the rapidly expanding metals industries.

More practical considerations also indicate the need for a drastic increase in membership in The Metallurgical Society. Budget limitations imposed by membership levels are making it difficult for headquarters to perform the services which members expect and to which they are entitled. Moreover, more complete coverage of metallurgical activities, to which the JOURNAL OF METALS is dedicated, will become possible only with increased circulation and attendant increases in advertising. Thus, a sound publications program is dependent on greatly increased membership.

Recognizing this, and working with R. W. Shearman, Metallurgical Society Secretary, the Membership Committee of The Metallurgical Society met last June to discuss and approve in large measure a complete, integrated and continuing membership program, to become effective as soon as possible. The newly appointed Assistant Secretary of The Metallurgical Society, Douglas C. Johnston, was assigned to implement and coordinate in detail the broad facets of the program. To date he has made considerable progress with regard to laying the foundations of the program, but considerable time will elapse before it can become fully effective.

The need for an organized membership drive is highlighted by the gap between actual membership gains this year and the goal of 3,000 new AIME members on which the budget is based. In an effort to make this goal a reality, and as a primer for the larger program to come, an intensive short range membership mailing program will be conducted during the last three months of this year. Based on prospect solicitation, personal items in metalworking magazines, and non-member registration at recent meetings, a mailing will be made this month of new membership material, including a revised application for membership.

Our goal for the end of the year is 500 new members, excluding students, as represented by new applications received starting October 1. Obviously, we will not receive this many replies from a mailing campaign, so the real work of meeting the quota falls to the individual members of the Society. On the basis of about 25 local sections having any considerable number of Metallurgical Society members, this amounts to a quota of 20 new members for each local section during the last months of this year. In effect, then, each local section having Metallurgical Society members is asked to obtain seven new members a month for the rest of this year. It is easy to see that we might easily double or triple such a goal, if every member were to make membership his prime concern through the end of this year. Applications will be available; headquarters stands ready to help you at your request, but they cannot ask the 500 new members personally to join! Only you can do that, by:

1. Encouraging the use of distinctive non-member badges at local section meetings as well as technical, regional, and Society meetings;
2. Welcoming non-members to meetings and inviting them to join The Metallurgical Society of AIME; and
3. Assisting new members in completing applications and answering their questions about the Society.

The experience of people who have worked in membership shows that our best prospects need very little actual selling; what they do need is to be asked to join. Introduce yourself to non-members at local section meetings and other AIME functions and ask them to join, volunteering to assist in completing the application. Remember that:

1. No cash is required at joining; new members are billed later;
2. Dues are prorated through the year, and the admission fee for associates and members may be paid in four $5 installments; and
3. The Metallurgical Society will assist in obtaining endorsers' signatures when necessary.

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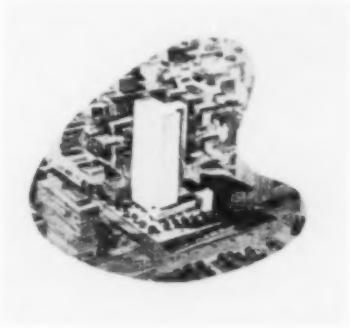
AIME NEWS

YOUR INVESTMENT IN THE ADVANCEMENT OF AMERICA'S ENGINEERING LEADERSHIP

—THE UNITED ENGINEERING CENTER



In maintaining leadership for this Country no group will play a more important part than engineers—men qualified by training, experience, and ability to meet the demands of an era that will witness technological and scientific progress surpassing anything known heretofore.

Within the past century the profession has increased mightily in stature. In numbers alone the five Founder Societies have grown elevenfold since 1907. Student members and members of the Associated Societies in the project swell the total to more than a quarter of a million.

Through their overall organizations the Societies have achieved a highly cooperative relationship, once symbolized and made effective in the present Engineering Societies Building, given by Andrew Carnegie half a century ago as "a home for engineers." This relationship is now to be renewed and strengthened in the new United Engineering Center.

Constructed more than 50 years ago, the present headquarters of the Founder Societies at 29 W. 39th St. was both attractive and ample in size during those untroubled days when Theodore Roosevelt was President of the United States and membership of the societies was but 16,000. *Today*, the structure is outdated and completely inadequate to the needs of a membership that has jumped to 180,000 and is still growing.

The new center is to be THE CENTER of the engineering profession—The impressive 20-story tower will be entirely functional, standing as enduring evidence of the unity and strength of the engineering profession. The Center will contain 250,000 sq ft of floor space, to meet all present requirements of the Founder Societies and provide for the various associate societies that desire to have their headquarters in the new building. In addition the design provides for expansion with continuing growth of the profession.

Everything about the Center will be designed with a single purpose in mind—effective, efficient, and economical service to member engineers throughout the country and wherever they may be. It will improve service to members, provide distinct economies through joint operations, and advance the individual members' continuing quest for knowledge.

An Investment to Further Engineering Progress—This is not a small project. Total cost of the new United Engineering Center, including the site, is estimated at $10 million. Of this more than two thirds—$7 million—will be met by present resources of the United Engineering Trustees and through the $5 million Industrial Gifts Campaign. Industry has already subscribed more than two thirds of its share.

What Will the Engineers Do for Themselves?—To the individual member the Member Gifts Campaign is both a challenge and an opportunity.

It is a challenge to you as a member of a true profession to give generous support to the most significant project your profession has undertaken during your lifetime.

(Continued on page 684)

UN Conference on the Peaceful Uses of Atomic Energy Held

In a successful effort to pool their latest knowledge on nuclear research, a legion of some 5000 scientists and delegates convened at the Second United Nations Conference on Peaceful Uses of Atomic Energy, at Geneva, September 1st, to 13th.

The conference was planned by the UN's seven-nation Advisory Committee on the Peaceful Uses of Atomic Energy at a series of meetings held in Geneva and at UN Headquarters in New York. It was composed of scientists named by the

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AIME BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► The newly established Carolina Subsection has been authorized to change its name to Western Carolina Subsection, since there is an Eastern North Carolina Subsection of the Southeast Section.

► The revised bylaws of the Southern California Petroleum Section have been approved, including a change of name to Los Angeles Basin Section.

► Scott Turner has been appointed by President Kinzel to be AIME's Official Delegate at the World Power Conference Section Meeting, Sept. 7 to 11, 1958, in Montreal, Canada.

► The Rocky Mountain Income Fund Committee has agreed to supply the Seeley W. Mudd Memorial Fund Committee with copies of the *Porphyry Coppers in 1956* at cost for free distribution to new Junior Members of AIME.

Swedes Celebrate Steel Centenary

Directors Gösta Westerberg, and Wilhelm Haglund of Sandvik, stand ready to place a wreath on the statue of G. F. Göransson, on the occasion of the centenary celebrations, July 1958 in Sweden.

Sweden jubilantly celebrated the centenary of Göran Fredrik Göransson's first successful commercial adaptation of the bessemer process. The commemoration of this milestone in Swedish steel history was culminated by a large gathering, including many noted steel experts, at the Sandvikens Jernverk, (Sandvik steel works) in central Sweden. The Sandvik Steel works, was originally founded with the aim of exploiting the findings resulting from the experiments at the nearby Edsken blast furnace plant. It was here that G. F. Göransson mastered the bessemer process, in July, 1958.

Other highlights of the celebration included a special stamp in honor of the occasion, issued by the Swedish Post Office. The 200 year old Swedish Ironmasters' Association coined a special gold medal in honor of Göransson and Sandviken's achievements—a very rare distinction.

At the time Göransson perfected the bessemer process, the British exploiters of the patents were still subjected to much disappointment, and had even begun to lose faith in the method. However, the epochmaking Swedish success fused new life into the experiments, and it was not long before the bessemer method made rapid progress all over the world.

Göransson's success was due mainly to his courage, tenacity, and enthusiasm for the untried, as well as the availability in Sweden of so many different types of highgrade ores. Continuing his experiments, Göransson invested his own and borrowed capital. Along with his collaborators, he found that sulfurous ores were unsuitable, that a slight manganese content was beneficial for the softer types of steel, and that the air blowing process gave hotter and quicker steel when the tuyeres had become worn.

After systematic experimentation with the various methods of furnace design, changes in the technique of tapping, and so on, the Edsken explorers finally arrived at a point where they had the bessemer method under full control. It is known that the smiths possessed a high degree of skill—and had to, being responsible for the quality of the steel.

Several years later, Göransson founded Sandviken in order better to exploit the bessemer method. It is a unique feature in the history of the Swedish iron trade that a new steel works should have been established expressly for the application of a novel new method of production. The output rapidly increased, and Sandviken was soon to be known for the high-quality steel for which it has become famous the world over.

New Engineering Center

(*Continued from page 683*)

In contrast to other annual appeals for funds, the Member Gifts Campaign is an opportunity to make a once-in-a-lifetime gift. Moreover, your gift as a member will serve as an ever greater stimulation to the Industrial Gifts Campaign.

The overall program calls for utilization of three sources of funds to meet the $10 million goal of the building project: Present UET resources, $2 million; Business and Industry, $5 million; and $3 million from the Member Gifts Campaign. AIME's proportionate share of the membership campaign is $500,000. (This has been divided among the Founder and associate societies in proportion to membership.)

AIME appointed J. L. Gillson, Vice President and nominee for President-Elect in 1959 as overall chairman of its share of the fund drive. Three well known members assisting Vice President Gillson are Evan Just for SME, O. B. J. Fraser for TMS, and M. Haider for SPE.

The industrial campaign has already received massive support and is well on its way toward the final goal. AIME has led in this share of the fund raising program. Under Vice President Gillson, the Member Gift Campaign is off to a good start. In the first phase, some leading members are being canvassed personally —in coming weeks the entire membership will be canvassed.

From the very beginning, the fund drive has had the wholehearted support of a veritable *Who's Who* of American industry, engineering, and education. No finer endorsement can be quoted than that of the nation's most honored engineer:

"We urgently need to start our new building. It is of national importance. We need the support of all our members."—*the Honorable Herbert Hoover.*

Atom Conference

(*Continued from page 683*)

Governments of Brazil, Canada, France, India, the USSR, the UK, and the US, with Secretary-General Dag Hammarskjold presiding.

In 77 different sessions, and through the media of films and exhibits, the program covered among other things, the possibility of producing power through fusion of lightweight atomic nuclei, progress in power production through fission of heavy nuclei, the use of nuclear energy to heat homes, propel ships and aircraft, study and treat diseases, improve agriculture crops, and speed up industrial processes, and recent advances in basic knowledge of the structure of matter.

There were 55 meetings at the first UN conference on peaceful uses of nuclear energy in 1955. This year's new 77-meeting program was favorably worked out so as to comprise a series of general sessions and five technical sessions, arranged in such a way that, during most of the conference, there were five simultaneous meetings every morning and afternoon. No less than 66 countries were represented at the two-week conference.

Visitors viewed the scientific exhibition, which was part of the conference, on the grounds of the Palais des Nations in Geneva. Here, there were displays set up by 20 nations including the Joint Institute for Nuclear Research at Dubnacma, USSR, and CERN (the European Center for Nuclear Research). Nearly 50 US companies, and the US Atomic Energy Commission participated with imposing exhibits.

Of the 2418 papers submitted to the Conference, some 650 were presented orally. This year's conference proceedings will be published in three volumes, and publication of the proceedings is expected to be completed by June 1959.

A review of metallurgical information revealed at the conference will be published in the November issue of JOURNAL OF METALS.

To Hold Liquid Phase Sintering Symposium at The Fall Meeting

The following Symposium was not listed in the Program and Abstracts of The Fall Meeting of The Metallurgical Society, September issue of JOURNAL OF METALS.

THURSDAY, OCTOBER 30

2:00 to 5:00 pm, Lorenzo Carter

Symposium on Liquid Phase Sintering

(Sponsored by the Powder Metallurgy Committee)

F. V. Lenel and J. E. Burke, Chairmen

The Kinetics of Densification During Sintering: W. D. Kingery, Massachusetts Institute of Technology.

Study of Grain Shape in Cemented Titanium Carbide: M. Hunetik, Jr. and T. J. Whalen, Ford Motor Company.

Development of Microstructure During Liquid Phase Sintering: J. T. Norton and L. Skolnick, Massachusetts Institute of Technology.

A Study of the Structure and Sintering Mechanism of Cemented Carbides: J. Gurland, Brown University.

IRSID—2nd International Sintering Symposium Proceedings are now off the press in two volumes, 644 pp., on sale for $12.00 at *IRSID, Documentation Dept., St. Germain-en-Laye (S&O) France.*

Need Increased Membership Activities

With the AIME membership newsletter showing a net gain of almost 1700 members so far this year, the need for membership activities at Metallurgical Society meetings is well illustrated. Only through such activities will the Society do its part in helping the AIME reach its goal of 3000 new members by the end of 1958.

In speaking of the need for new members, it is easy to give the erroneous impression that membership activities should be concerned only with persuading new individuals to join AIME. Actually, it is as essential, if not more important, to minimize losses of present members. This tabulation of The Metallurgical Society membership figures shows the effect of high losses on seemingly high gains.

Division	Gains	Losses	Net
ISD	209	79	130
EMD	86	49	37
IMD	110	134	−24
unclass.	256	85	171
Total	661	347	314

The large unclassified figure is a result of the automatic change of status from student to junior members, which occurs every year in June with the graduation of the former.

In order to reach its goal of 500 new members by the end of 1958, The Metallurgical Society, through its members, must obtain more than 200 new members during the next month. This should maintain the desired level when normal losses take their toll. This represents only three new members per local section this month. This month's editorial on p. 682, tells why we must change the slope of the membership curve. Welcome a non-member to your next local section meeting where he may see for himself why THE METALLURGICAL SOCIETY OF AIME is the leading organization for the professional metals man.

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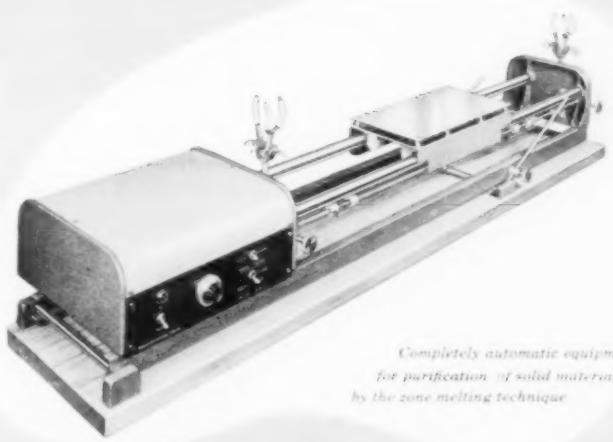

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Map, Location, and Identification of AIME Local Sections

Alphabetical Listings Below Include the Name and Address of the Local Section Secretary or Secretary-Treasurer. Subsections and/or Groups Are Given After Section Name.

50—Adirondack
Severn P. Brown, St. Joseph Lead Co., Balmat, N. Y.

1—Alaska
Douglas W. Huber, School of Mines, University of Alaska, P.O. Box 337, College, Alaska.

2—Arizona. Subsections: Ajo, Bisbee-Douglas, Morenci, Yavapi
C. L. Hoyt, P.O. Box 515, Ray, Ariz.

58—Arkansas
David J. White, P.O. Box 126, Bauxite, Ark.

66—Billings Petroleum
Don M. Madden, Mobil Producing Co., Box 2548, Billings, Mont.

3—Black Hills
Joel Waterland, Mine Dept., Homestake Mining Co., Central City, S. D.

4—Boston
J. H. Brown, Dept. of Metallurgy, Massachusetts Inst. of Technology, Cambridge 39, Mass.

78—California Coastal
Jack Biren, Continental Oil Co., Box 451, Ventura, Calif.

5—Carlsbad Potash
Ralph E. Littrell, National Potash Co., P.O. Box 731, Carlsbad, N. M.

6—Central Appalachian
Charles T. Holland, P.O. Box 836, Blacksburg, Va.

60—Central New Mexico
V. L. Hill, 1309 North Second, Grants, N. M.

7—Chicago
J. V. Russell, Republic Steel Corp., 11600 Burley Ave., Chicago 17, Ill.

8—Cleveland
Frank A. Zorko, Cleveland Welds, General Electric Co., Nela Park, Cleveland 12, Ohio.

9—Colorado. Subsections: Intermountain, Pikes Peak, MBD
Arthur L. Hill, National Fuse & Powder Co., 3801 Delgany St., Denver, Colo.

57—Colorado Plateau
T. S. Ary, 1340 Houston Ave., Grand Junction, Colo.

10—Columbia. Subsections: Snake River, Coeur d'Alene, Spokane
Carlos E. Milner, Jr., Box 1121, Spokane 10, Wash.

11—Connecticut
Robert S. Bray, Chase Brass & Copper Co., Waterbury, Conn.

55—Dallas
W. F. West, Estate of J. B. Stoddard, 500 Trinity University Bldg., Dallas, Texas.

12—Delta
F. J. Olivier, Humble Oil & Refining Co., P.O. Box 626, New Orleans, La.

65—Denver Petroleum. Subsections: Uintah Basin, Colorado-Nebraska
W. E. Bauman, Gulf Oil Corp., P.O. Box 2097, Denver, Colo.

13—Detroit
K. B. Valentine, Pontiac Motors Div., General Motors Corp., Pontiac 11, Mich.

14—East Texas
Hugh B. Barton, Humble Oil & Refining Co., Box 2025, Tyler, Texas.

15—El Paso
Guy E. Ingersoll, Texas Western College, El Paso, Texas.

71—Evangeline
Jack Mahan, Jr., Pan American Petroleum Corp., Box 583, Lafayette, La.

45—Florida
Harvey B. Hardy, Georgia Iron Works, P.O. Box 509, Bartow, Fla.

54—Fort Worth
Walter L. Hahn, The Texas Co., Continental Life Bldg., Box 1720, Fort Worth, Texas.

77—Four Corners Petroleum
Thomas A. Dugan, Pacific Northwest Pipeline Corp., 405½ West Broadway, Farmington, N. M.

73—Great Bend
Stephen F. Hoss, Perforating Guns Atlas Corp., Box 259, Great Bend, Kan.

16—Gulf Coast
Bob Diggs Brown, Halliburton Oil Well Cementing Co., 512 Esperson Bldg., Houston 2, Texas.

61—Hobbs
Robert N. Miller, Tidewater Oil Co., Box 547, Hobbs, N. M.

62—Hugoton
Gale T. Bradshaw, Schlumberger Well Surveying Corp., Box 512, Liberal, Kan.

68—Illinois Basin Petroleum
Elmer A. Milz, Shell Oil Co., Petroleum Bldg., Centralia, Ill.

17—Kansas
James J. Jamieson, Gulf Oil Corp., Box 2233, Wichita, Kan.

18—Lehigh Valley
Noel N. Moebs, Geological Dept., The New Jersey Zinc Co., R.D. #1, Center Valley, Pa.

52—Lou-Ark
Paul S. Clinkenbeard, Dowell Inc., 1102 Beck Bldg., Shreveport, La.

19—Mid-Continent
H. Arthur Nedom, Amerada Petroleum Corp., Tulsa, Okla.

20—Minnesota. Subsections: Mining, Minerals Beneficiation
R. L. Bennett, Research Laboratory, Oliver Iron Mining Div., 4832 Grand Ave., Duluth, Minn.

56—Mississippi
Wilbur Lilly, Gulf Oil Corp., Box 1269, Jackson, Miss.

21—Montana
C. J. Hicks, The Anaconda Co., 526 Hennessy Bldg., Butte, Mont.

22—Nevada. Subsections: Reno, Southern Nevada, Eastern Nevada
John G. Smith, Box 141, Ruth, Nev.

23—New York. Groups: Physical Metallurgy, Powder Metallurgy
David T. Steele, American Metal Climax Inc., 61 Broadway, New York 6, N. Y.

67—New York Petroleum
Todd L. Tapp, California Texas Oil Co., 380 Madison Ave., New York 17, N. Y.

64—Niagara Frontier
J. D. Roach, TAM Div., National Lead Co., Niagara Falls, N. Y.

25—North Pacific
Merrill C. Teats, American Smelting & Refining Co., Tacoma Smelter, Tacoma, Wash.

24—North Texas
Don V. Hester, The Texas Co., Box 600, Wichita Falls, Texas.

26—Ohio Valley
J. R. Lucas, Ohio State University, Columbus, Ohio.

27—Oklahoma City
Eugene N. Bennett, Pan American Petroleum Corp., P.O. Box 1654, Oklahoma City, Okla.

28—Oregon
Don W. Johnson, Reynolds Metals Co., Longview, Wash.

63—Panhandle
Albert S. Knox, Gulf Oil Corp., Box 751, Borger, Texas.

29—Pennsylvania-Anthracite
Emerson H. Todd, American Chain & Cable Co., 271 S. Pennsylvania Ave., Wilkes-Barre, Pa.

30—Permian Basin
J. B. Markolf, Schulmberger Well Surveying Corp., Route 1, Box 5X, Midland, Texas.

31—Philadelphia
James M. B. Keyser, Allen-Sherman-Hoff Pump Co., 259 East Lancaster Ave., Wynnewood, Pa.

32—Pittsburgh. Subsections: Petroleum; Groups: Minerals Industry, Institute of Metals
R. S. Crowell, U.S. Steel Corp., Clairton Works, Clairton, Pa.

81—Roswell Petroleum
Rex C. Cabaniss, Box 845, Roswell, N. M.

33—St. Louis
Gordon M. Bell, Alcoa Research Laboratories, P.O. Box 497, East St. Louis, Ill.

34—San Francisco
L. A. Norman, Jr., 41 Sutter St., Room 709, San Francisco, Calif.

59—San Joaquin Valley
A. J. Horn, Standard Oil Co. of California, 11-C Camp, Taft, Calif.

80—Snyder
E. L. Epley, Magnolia Petroleum Co., Box 815, Snyder, Texas.

53—South Plains
R. J. Boren, 1307 East Hester St., Brownfield, Texas.

35—Southeast. Subsections: Carolina, Eastern North Carolina, Knoxville Area
L. S. Chabot, Jr., 2705 Shades Crest Rd., Birmingham 9, Ala.

36—Southern California. Subsections: Southern Sierra
A. T. Cape, 724 South Victory Blvd., Burbank, Calif.

69—Southern California Petroleum
W. F. Cerini, Union Oil Co. of California, 9675 S. Santa Fe Springs Rd., Whittier, Calif.

37—Southwest Texas. Subsections: Austin-San Antonio
W. J. Bielstein, Humble Oil & Refining Co., P.O. Box 1271, Corpus Christi, Texas.

48—Southwestern Alaska
William Powell, Territorial Dept. of Mines, 329 Second Ave., Anchorage, Alaska.

38—Southwestern New Mexico
David W. Boise, 917 West St., Silver City, N. M.

44—Spindletop
Carl B. Rush, Pan American Petroleum Corp., Box 5038, Beaumont, Texas.

39—Tri-State
Hugh Wright, Tri-State Zinc & Lead Ore Producers Assn., P.O. Box 36, Picher, Okla.

74—Upper Mississippi Valley
Thomas E. Mullens, P.O. Box 165, Platteville, Wis.

40—Upper Peninsula
Roy W. Drier, McNair Hall, Michigan College of Mining & Technology, Houghton, Mich.

75—Uranium
R. W. Unger, 477 W. Andrea Ct., Moab, Utah.

41—Utah
P. H. Ensign, Kennecott Copper Corp., Arthur Plant, Garfield, Utah.

42—Washington, D. C.
Albert E. Schreck, 726 Jackson Ave., Falls Church, Va.

49—West Central Texas
L. D. Webster, Katz Oil Co., 428 Petroleum Bldg., Abilene, Texas.

43—Wyoming
D. L. Garthwaite, Pan American Petroleum Corp., P.O. Box 40, Casper, Wyo.

83—Wyoming Mining and Metals
John Atkins, 306 Antelope Dr., Riverton, Wyo.

Foreign Sections

76—Caracas Petroleum
E. A. Moore, Cia. Shell de Venezuela, Apartado 809, Caracas, Venezuela.

79—CIM-AIME Calgary Petroleum Engineering Section of the Petroleum and Natural Gas Div., CIM
J. R. Lyon, Shell Oil Co., Box 100, Calgary, Alberta, Canada.

82—CIM-AIME Edmonton Petroleum Engineering Section of the Petroleum and Natural Gas Div., CIM
V. E. Bohme, Oil & Gas Conservation Board, Room 330, Natural Resources Bldg., Edmonton, Alberta, Canada.

70—Eastern Venezuela Petroleum
Roger D. West, Mene Grande Oil Co., Apartado 3947, Caracas, Venezuela.

51—Lima, Peru
Walter E. King, Av. Santa Cruz 331, Miraflores, Lima, Peru.

47—Mexico
John T. Carty, Dolores 17-901, Mexico 1, D.F., Mexico.

46—Philippine
Nestorio N. Lim, 26 Montreal St., Univ. Subd. Cubao, Quezon City, P.I.

72—Western Venezuela Petroleum
R. L. Seay, Jr., c/o Richmond Exploration Co., Apartado 95, Maracaibo, Venezuela.

Local Section Membership Chairmen

List includes only Sections to which SME members belong.

50—Adirondack
Charles R. Barton, Jr., Barton Mines Corp., North Creek, N. Y.

1—Alaska
D. P. Colp, 644 8th Ave., Fairbanks, Alaska.

2—Arizona
Reed F. Welch, American Smelting & Refining Co., 810 Valley National Bldg., Tucson, Ariz.

58—Arkansas
Jack C. McFarlin, Ore Control Engineer, Reynolds Mining Corp., Bauxite, Ark.

3—Black Hills
Rex Tario, Homestake Mining Co., Lead, S. D.

4—Boston
* J. H. Brown, Dept. of Metallurgy, Massachusetts Inst. of Technology, Cambridge 39, Mass.

5—Carlsbad Potash
J. E. Tong, Box 67, Carlsbad, N. M.

6—Central Appalachian
G. R. Spindler, Director, School of Mines, West Virginia University, Morgantown, W. Va.

60—Central New Mexico
R. J. Stoehr, 208 Smith St., Grants, N. M.

7—Chicago
E. C. Rudolphy, Chief Development Metallurgist, U.S. Steel Corp., South Works, 3426 E. 89th St., Chicago, Ill.

8—Cleveland
* Frank A. Zorko, Cleveland Welds, General Electric Co., Nela Park, Cleveland 12, Ohio.

9—Colorado
Fred L. Smith, Manager, Mining Div., Colorado School of Mines Research Foundation Inc., Golden, Colo.

57—Colorado Plateau
J. William Hasler, 1350 N. 18th, Grand Junction, Colo.

10—Columbia
Ed Oman, Manager, Mining Dept., Western Machinery Co., Spokane Div., Spokane, Wash.

11—Connecticut
John P. Lynch, Jr., Research Assistant, American Brass Co., Waterbury, Conn.

55—Dallas
Margaret Keiles, Assistant Research Chemist, Atlantic Refining Co., Box 2815, Dallas, Texas.

12—Delta
Dale H. Aunspaugh, Gulf Refining Co., Houston Products Div., P.O. Drawer 37, Harvey, La.

13—Detroit
R. A. Wilde, Eaton Manufacturing Co., 9771 French Rd., Detroit 13, Mich.

15—El Paso
Robert McGeorge, Ore Buyer & Assistant to Manager, American Smelting & Refining Co., 700 Crandall Bldg., Salt Lake City, Utah.

45—Florida
James L. Cox, P.O. Box 867, Bartow, Fla.

16—Gulf Coast
Patrick Broussard, Assistant Div. Engineer, Halliburton Oil Well Cementing Co., 512 Esperson Bldg., Houston, Texas.

17—Kansas
William R. Franey, District Engineer, Stanolind Oil & Gas Co., Room 1039, First National Bank Bldg., Wichita, Kansas.

18—Lehigh Valley
A. T. Kaufman, Bethlehem Steel Corp., Room 1307, Main Office, 3 St., Bethlehem, Pa.

19—Mid-Continent
Virgil J. Berry, Jr., Group Supervisor, Stanolind Oil & Gas Co., Research Dept., Tulsa, Okla.

20—Minnesota
R. C. Ferguson, Hardinge Co. Inc., York, Pa.

56—Mississippi
James M. Otts, Jr., Zone Petroleum Engineer, Gulf Oil Corp., Box 638, Laurel, Miss.

21—Montana
Koehler Stout, Assistant Professor of Mining Engineering, Montana School of Mines, Butte, Mont.

22—Nevada
A. L. Engel, U.S. Bureau of Mines, 1605 Evans Ave., Reno, Nev.

23—New York
George P. Lutjen, District Manager, Coal Age and Engineering & Mining Journal, 500 Fifth Ave., New York, N. Y.

64—Niagara Frontier
C. H. Emery, 58 Windermere Rd., Lockport, N. Y.

25—North Pacific
Martin L. Plass, Assistant General Superintendent, American Smelting & Refining Co., Box 1111, El Paso, Texas.

26—Ohio Valley
W. J. King, Kaiser Aluminum & Chemical Corp., Newark, Ohio.

28—Oregon
Ralph Ferguson, Gladding McBean & Co., 110 S.E. Main St., Portland, Ore.

29—Pennsylvania-Anthracite
J. T. Griffiths, 340 N. Bromley Ave., Scranton 4, Pa.

31—Philadelphia
Robert B. Brackin, Engineering Dept., Du Pont de Nemours & Co., Wilmington, Del.

32—Pittsburgh
* R. S. Crowell, U.S. Steel Corp., Clairton Works, Clairton, Pa.

33—St. Louis
V. W. Buys, 1915 Washington Ave., St. Louis 3, Mo.

Numerical Local Section Code to Map

1	Alaska	29	Penn.-Anthracite	57	Colorado Plateau
2	Arizona	30	Permian Basin	58	Arkansas
3	Black Hills	31	Philadelphia	59	San Joaquin
4	Boston	32	Pittsburgh	60	Central New Mexico
5	Carlsbad Potash	33	St. Louis	61	Hobbs
6	Central Appalachian	34	San Francisco	62	Hugoton
7	Chicago	35	Southeast	63	Panhandle
8	Cleveland	36	Southern California	64	Niagara Frontier
9	Colorado	37	Southwest Texas	65	Denver Petroleum
10	Columbia	38	Southwestern New Mexico	66	Billings Petroleum
11	Connecticut	39	Tri-State	67	New York Petroleum
12	Delta	40	Upper Peninsula	68	Illinois Petroleum Basin
13	Detroit	41	Utah	69	So. California Petroleum
14	East Texas	42	Washington, D. C.	70	Eastern Venezuela Petroleum
15	El Paso	43	Wyoming	71	Evangeline
16	Gulf Coast	44	Spindletop	72	West Venezuela
17	Kansas	45	Florida	73	Great Bend
18	Lehigh Valley	46	Philippine	74	Upper Mississippi
19	Mid-Continent	47	Mexico	75	Uranium
20	Minnesota	48	Southwestern Alaska	76	Caracas
21	Montana	49	West Central Texas	77	Four Corners
22	Nevada	50	Adirondack	78	California Coastal
23	New York	51	Peru	79	CIM-AIME Calgary
24	North Texas	52	[illegible] Ark	80	Snyder
25	North Pacific	53	South Plains	81	Roswell
26	Ohio Valley	54	Fort Worth	82	CIM-AIME Edmonton
27	Oklahoma City	55	Dallas	83	Wyoming Mining & Metals
28	Oregon	56	Mississippi		(Location not given on map)

34—San Francisco
L. Kenneth Wilson, American Smelting & Refining Co., 405 Montgomery St., San Francisco 4, Calif.

59—San Joaquin Valley
J. H. Sutton, 2908 Berger St., Bakersfield, Calif.

35—Southeast
R. S. White, 249 Flint Dr., Fairfield, Ala.

36—Southern California
John H. Eggers, 8121 West Blvd., Inglewood 4, Calif.

37—Southwest Texas
James J. McMahon, Shell Oil Co., P.O. Box 1861, Corpus Christi, Texas.

48—Southwestern Alaska
Martin W. Jasper, Territorial Dept. of Mines, Box 2139, Anchorage, Alaska.

38—Southwestern New Mexico
Robert W. Shilling, Kennecott Copper Corp., Box 966, Santa Rita, N. M.

39—Tri-State
(Tri-State) Claude O. Dale, Assistant General Manager, Mining & Smelting Div., Eagle Picher Co., Miami, Okla. (SME Mining & Exploration Div.) Richard C. Lundin, Eagle Picher Co., Cardin, Okla.

74—Upper Mississippi Valley
John M. Hague, 521 Rountree Ave., Plattville, Wis.

40—Upper Peninsula
W. Seppanen, Pickands Mather & Co., Caspian, Mich.

75—Uranium
Edwin Wood, Hidden Splendor Mining Co., Moab, Utah.

41—Utah
E. K. Olson, Jr., Utah Copper Div., Kennecott Copper Corp., Salt Lake City, Utah.

42—Washington, D. C.
* Albert E. Schreck, 726 Jackson Ave., Falls Church, Va.

43—Wyoming Mining and Metals
Robert Ford, 206 S. Broadway, P.O. Box 426, Riverton, Wyo.

70—Eastern Venezuela Petroleum
Jay G. Hautemen, AZ Export, Apartado 4026, Puerto La Cruz, Venezuela.

47—Mexico
Georges Ordonez, Avenida Juarez No. 134, Mexico D.F., Mexico.

46—Philippine
* Nestorio N. Lim, 26 Montreal St. Univ. Subd. Cubao, Quezon City, P.I.

* Refers to Secretary of Section where a Membership Chairman is not listed.

Free Price List of AEC Reports

A new free price list of Atomic Energy Commission unclassified research reports for sale by the Office of Technical Services, US Dept. of Commerce, is now available from OTS on request.

This cumulative listing of more than 4000 AEC reports in the OTS collection includes new documents acquired since January 1958. To obtain the new list, request **AEC Research Reports Price List No. 30,** from *Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.*

OBITUARIES

Donald M. Liddell
An Appreciation by
Philip D. Wilson

On August 16, 1958, in his 80th year, Lt. Col. Donald M. Liddell, a member since 1916, passed away. Colonel Liddell's health had been gradually failing for more than a year, but his fortitude remained. On January 29, 1958, he received the *Gold Medal of the Mining and Metallurgical Society of America* at the Society's annual dinner at the Princeton Club of New York. On this occasion, he made a speech of acceptance in which he discussed the history of the medal and the accomplishment of the fourteen prior recipients since it was first bestowed jointly on Mr. and Mrs. H. Hoover in 1914. Colonel Liddell's citation was *Unusual Contribution to the Art of Non-Ferrous Metallurgy and Research in Connection Therewith.*

He was to the day of his death a distinguished metallurgist. He started his career, after graduation from John Hopkins in 1900, in copper, lead smelting and refining, in Morenci, Ariz., Baltimore, Md., Chrome, N. J., and Graselli, Ind. During and after this period, he served on the editorial staff of the Engineering and Mining Journal. He concluded this phase of his career in 1913-16 as managing editor of the magazine. During the First World War he served as a captain, and in World War II, he was a Lieutenant Colonel in the army.

From 1919 to 1936, he was a partner in the consulting firm of Weld and Liddell. He also acted as president, consulting engineer, and director of numerous corporations during this period. In his later years he served as director of the National State Bank of Elizabeth, N. J.

Colonel Liddell was involved in the exploration of the lateritic deposits in Cuba from their beginning, and these were subsequently developed by Pardners Mines Corp. and later exploited and operated by the Freeport Sulfur Co. Colonel Liddell was a director of the Nicaro Nickel Co. and was in charge of the Moa Bay project. Nicaro Nickel contributed largely during World War II, and the Moa project is now being prepared for large productions of nickel.

Colonel Liddell was the author of the *Metallurgist and Chemists' Handbook*, 1916, which had three editions and of the *Handbook of Chemical Engineering*, 1922, which had two editions. In 1926, he wrote the *Handbook on Non-Ferrous Metallurgy* with revised editions in 1931, 1946. He was co-editor with Dr. H. Foster Bain, 1922, of *International Control of Mineral Resources*, and co-author with Kenneth Leith, 1931, of *Mineral Resources of the United States, and its Capacity to Produce*. He was also co-author with Gilbert Doan, 1933, of the *Principles of Metallurgy*, and with Jean Maunoury and G. A. Pfeiffer in 1937, of *Chessmen*.

In 1955 Colonel Liddell was elected president of the Mining and Metallurgical Society of America, after having served as its secretary for a number of years. From 1947-49, he was president of the Mining Club of New York. He was a honorary member of the Chemical, Metallurgical, and Mining Society of Africa, and a member of AIME.

Colonel Liddell, blessed with a pleasing personality, will be missed by his many friends. He is survived by

Change of Address and Personals Form

To be sure that you receive your publications and correspondence promptly, please fill in the form below and send it to **The Metallurgical Society of AIME**, 29 W. 39th St., New York 18, N.Y.:

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his widow, Edith (Stabler) Liddell, one son, Lt. Col. Donald M. Liddell, Jr., and daughter Edith (Mrs. J. Russell Twiss) and five grandchildren.

Martinus Hendrieus Caron

An Appreciation
Taken from
de Ingenieur (March 28, 1958)

Martinus Hendrieus Caron (Member 1918), leading metallurgist in the fields of nickel and cobalt, died at his home in The Hague, on February 20th. Dr. Caron's patents on nickel induced many companies to build installation plants, including Canada and Cuba. The United States also granted a patent for this process. The Caron experiments proved that silver was soluble only after the reduction of the silver manganese oxides. The government of the Dutch East Indies asked Caron to come to the US in order to design a test installation in cooperation with the "Experiment Station" at Golden, Colo., Bureau of Mines.

Prof. Caron was a metallurgist at the Technische Hogeschool and retired at the age of 68. From 1946-51 he was a member of the managing board of the Royal Institute of Engineers and president of its mining department.

Prof. Caron wrote extensively in his field, the latest piece appearing in the *Ingenieur*, in 1957.

J. C. Holford (Member 1947) died unexpectedly last Dec. 16, 1956. Mr. Holford, at the time of his death, had just been appointed national program chairman of the EMD division of The Metallurgical Society of AIME. After graduation from the University of Texas, Mr. Holford was employed as superintendent of Anita Copper Co. From 1926 until 1928, he served with the American Smelter and Refining Co., and in 1941 went to Morenci, Ariz. as a metallurgist. He was employed at Morenci at the time of his death.

Robert L. Sweet (Member 1950) associate professor of Metallurgurical Engineering at Michigan State College, died on March 17, 1958. Professor Sweet was an associate professor at the college since 1946. From 1944-46, Prof. Sweet was a member of the Chrysler Corp., Detroit, Mich., where he was in charge of projects relating to hardenability and fatigue. At the time of his death Prof. Sweet resided in Lansing, Mich.

Chester K. Sterrett, (Member 1952) manager of the industrial division of the Portland Chamber of Commerce since 1944, died on July 19, 1958. A graduate of the University of Cincinnati, he worked for 17 years at the Cincinnati Gas & Electric Co. In 1947, and up to the time of his death, he served as secretary-treasurer of the chamber's Raw Material Survey. Mr. Sterrett was a member of the Electrochemical Society, and the American Industrial Development Council.

Sivert J. Skogmo, (Member 1948) died in Norway on July 3, 1958. Mr. Skogmo was director of research and development at Det Norske Zinkkompani from 1946 until his death. Prior to this position, Mr. Skogmo was chief chemist and metallurgist for the company. A graduate of the Norwegian Technical University in 1922, Mr. Skogmo started his career as a researcher working on the corrosion of aluminum and the production of sulfur from pyrite at the metallurgical laboratory of Prof. Harald Pedersen, Sweden.

Daniel Ernest MacLean (Member 1954) vice president of Lava Crucible-Refractories Co., died on March 26, 1958. At the time of his death he resided in Pittsburgh, Pa.

John Covey Holford (Member 1947) smelter metallurgist for the Phelps Dodge Corp., died on August 8, 1958. Mr. Holford started his career in 1929 as a roaster foreman. He was a graduate of the Texas College of Mining and Metallurgy, and at the time of his death resided in Pheonix, Ariz.

Dana J. Demosest (Member 1919) professor of metallurgy at Ohio State University since 1907, died on June 30, 1958. Prof. Demoset would have been 76 years old this August. He was living in Columbus, Ohio, at the time of his death.

Paul Leslie Asnis, (Member 1955) metallurgist at the Wilbur B. Driver Company, N. J., died on February 22, 1957. Mr. Asnis was a member of Alpha Mu Epsilon, and received his M.S. degree from the Stevens Institute of Technology. At the time of his death Mr. Asnis resided in Pequannock, N. J.

NECROLOGY

Date Elected	Name	Date of Death
1955	P. L. Asnis	Feb. 22, 1957
1919	D. J. Demorest	June 30, 1958
1947	J. C. Holford	Aug. 8, 1958
1916	D. M. Liddell	Aug. 16, 1958
1954	D. E. MacLean	Mar. 26, 1958
1948	S. J. Skogmo	July 3, 1958
1952	C. K. Sterrett	July 19, 1958
1942	R. L. Sweet	Mar. 17, 1958

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Sept. 1, 1958 was 30,496; in addition 3,125 Student members were enrolled.

ADMISSIONS COMMITTEE

J. H. Scaff, Chairman; Alfred Bornemann; F. B. Foley; T. D. Jones; L. L. Seigle; J. M. Warde; H. K. Work.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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REINSTATEMENT—CHANGE OF STATUS

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Thoni V. Philip, Pittsburgh, Pa.
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Re-election

J. Frank Frain, Oakland, Calif.

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COMING EVENTS

Oct. 9-10, AIME NOHC Southwestern Section, fall meeting, Tutweiler Hotel, Birmingham, Ala.

Oct. 10, AIME NOHC Eastern Section, annual technical meeting, Warwick Hotel, Philadelphia.

Oct. 16, AIME Utah Section, *Progress in Air Pollution Control,* Salt Lake City.

Oct. 23-25, AIME, Society of Mining Engineers, and the Metallurgical Society, Mid-America Minerals Conference, Chase-Park Plaza Hotels, St. Louis.

Oct. 27-30, AIME Fall Meeting of The Metallurgical Society, sponsored by the Institute of Metals Division, Carter Hotel, Cleveland.

Nov. 7, AIME Pittsburgh Section, Thirteenth Annual Off-the-Record meeting, Pittsburgh.

Nov. 11, AIME NOHC Buffalo Local Section, fall meeting, Statler Hotel, Buffalo.

Nov. 17-20, The Fourth Conference on Magnetism and Magnetic Materials, sponsored by the AIEE, in cooperation with The Metallurgical Soc. of AIME, The American Physical Soc., the Inst. of Radio Engineers, and the Office of Naval Research, Sheraton Hotel, Philadelphia.

Dec. 3-5, AIME 16th Electric Furnace Conference, Statler Hotel, Detroit.

Dec. 11, AIME Utah Section, Panel discussion on the Place of Research in the Minerals Industries, Salt Lake City.

Feb. 15-19, 1959, AIME Annual Meeting, St. Francis Hotel, Sheraton-Palace Hotel, and Sir Francis Drake Hotel, San Francisco.

Apr. 2-3, 1959, AIME Technical Conference on Stress Corrosion, Mellon Institute, Pittsburgh.

Apr. 6-8, 1959, AIME 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Jefferson Hotel, St. Louis.

Apr. 5-10, 1959, Fifth Nuclear Congress, Cleveland Auditorium, Cleveland.

Apr. 27-30, 1959, AIME International Symposium on the Physical Chemistry of Process Metallurgy, Penn-Sheraton Hotel, Pittsburgh.

June 13-15, 1960, first International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPA.

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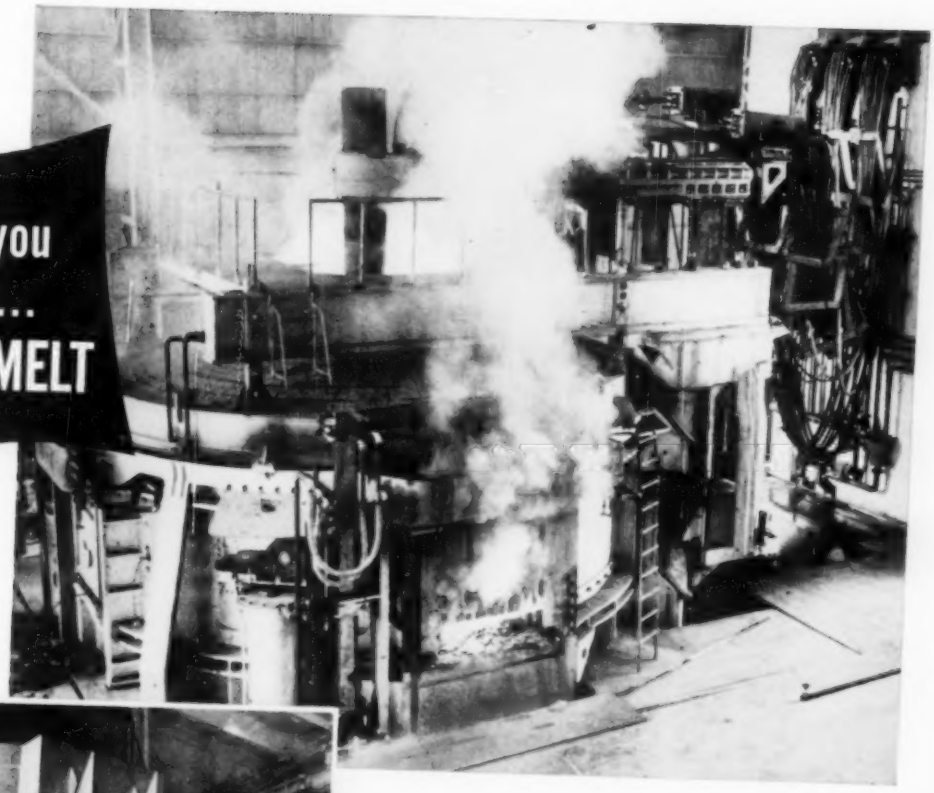

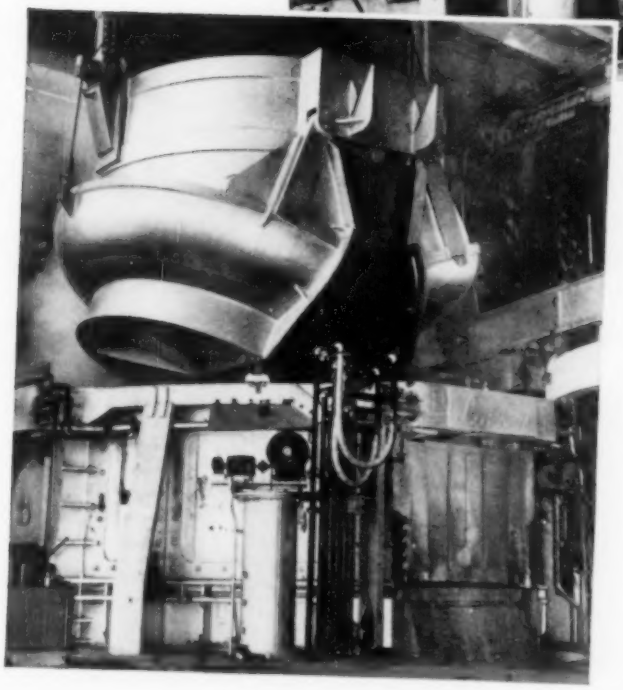

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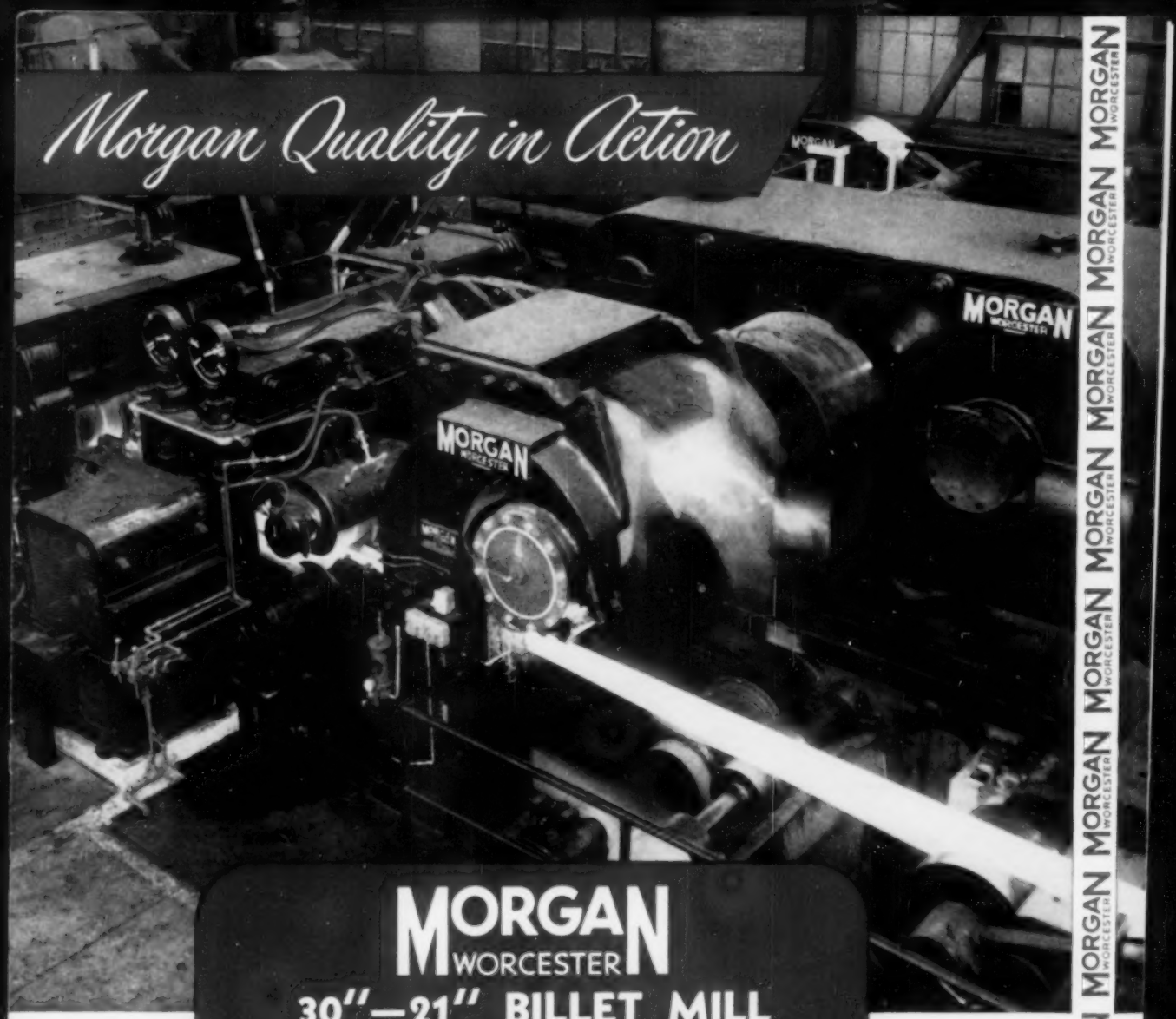

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